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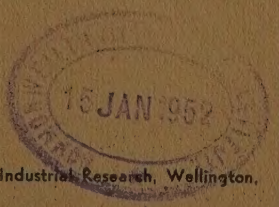

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(AGRICULTURAL RESEARCH SECTION)

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NOTICES

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DEVELOPMENTS IN AERIAL TOPDRESSING DURING 1949

By D. A. CAMPBELL,* Soil Conservation and Rivers Control Council, Ministry of Works, Wellington

(*Received for publication, 19 December 1949*)

Summary

The aerial topdressing service trial in the Wairarapa established the practicability of aerial topdressing on a number of widely dispersed farms on various types of country and confirmed the opinion that it was feasible to operate a topdressing service with a number of heavy aircraft. Farmers and agricultural experts were well satisfied with the distribution of the fertilizer and convinced of the future of the aeroplane as a new farm implement.

The aerial topdressing demonstration at Ohariu provided confirmation of the simplicity and precision of operation on typical, steep, hill country.

Accurate measurement and statistical analysis of the distribution over an area of 48 acres at Ohakea established the fact that almost perfect distribution could be obtained by flying at a height of 400 ft in parallel flights 75 ft apart with the present hopper 4/7ths opened. Investigations on various related aspects of the project have yielded further basic data. Aviation investigations are being carried on to increase the width and evenness of distribution, while precise information on the performance of suitable aircraft has been obtained. Investigations have shown that 2 mm diameter pellets of phosphate are desirable. The response to topdressing is conditioned by the clover content of the pastures which can be improved by oversowing and management.

The cost of aerial topdressing has been investigated and shown to be competitive with normal topdressing costs on difficult hill country and to vary from 6/- to 15/3 per acre for the application of 2 cwt of fertilizer. Some progress has been made with regional organization in anticipation of an aerial topdressing service.

The commercial operation of light aircraft to provide the beginnings of a topdressing service has been rapidly and effectively developed in the past six months and there are now eight companies operating which contract directly with farmers.

* Organizing Secretary of the Soil Conservation Council's Advisory and Co-ordinating Committee on the Aerial Distribution of Fertilizer and Seeds.

INTRODUCTION

The preliminary trials[1] carried out at the Soil Conservation Council's request by the Royal New Zealand Air Force (R.N.Z.A.F.), using a one-ton capacity Avenger aircraft, revealed the need of a vibrator to ensure regular flow of fertilizer from the hopper, and also the need for directing the pilot from the ground. These limitations were overcome by making the following alterations in design:—

The sides of the hopper were steepened to 60° slope and a high frequency vibrator rod with 4-in disks attached at one-foot intervals throughout the length of the hopper was installed inside it above the discharge openings (Fig. 1). A mobile ground control operator, equipped with two-way radio communcation, and operating from adjacent vantage points outside the dropping zone, directed the plane on each flight.

It was found that with the modifications described the "hillside" superphosphate flowed at an even rate from the hopper in 17 seconds, and no difficulty was experienced in bringing the aircraft in by radio direction from the ground control operator.

FIG. 1.—Fertilizer hopper being filled. (Note motor which actuates vibrator rod.)

These preliminary trials proved that distribution, placement of fertilizer, and flying control operated successfuly in small scale trials. The next step was to organize trials on a larger scale to evaluate the cost and feasibility of a miniature aerial topdressing service.[1]

AERIAL TOPDRESSING SERVICE TRIAL, WAIRARAPA

On the advice of its Advisory and Co-ordinating Committee the Soil Conservation and Rivers Control Council organized a 1,000-acre field trial in the Wairarapa, arranging with the R.N.Z.A.F. to carry out the topdressing, and with the farmers to pay for the fertilizer. The Council met the cost of transport and distribution by air, while a local sub-committee representing the Catchment Board, Federated Farmers and State Departments selected suitable properties and made the necessary local arrangements. From the numerous applications, 10 areas of approximately 80 to 100 acres on each farm were chosen in various parts of the district (from 8 to 35 miles from the aerodrome) to cover local variations in terrain, soil type, and pastures, in order to make the project typical for the rough hilly country which it is virtually impossible to topdress by existing methods.

The flying technique used in this trial and equipment employed for measuring distribution of fertilizer is described in detail by Greenall *et al.*[2]

A field day was arranged during the trials on Mr. H. Morrison's property, Awatoitoi (Figs. 2 and 3), where the operation was demonstrated on the steep rugged country adjacent to the homestead paddocks.

FIG. 2.—Operation on typical hill country, Wairarapa.

Results of Trial

When examined, the topdressed areas appeared to have had a light fall of hail. The uniformity of distribution, as measured by samplers, improved as the pilots gained experience during the project, and was better than could be obtained by other methods on such rugged country. The trials indicated that the R.N.Z.A.F. succeeded in evolving a satisfactory technique for operating and controlling a flight of aircraft engaged on aerial topdressing of rugged hill country at considerable distances from the aerodrome.

A comprehensive investigation into the operating costs of the Avenger aircraft was made by the R.N.Z.A.F. and these proved to be £15 per hour flying time. As a total flying-time of 53 hours was required to topdress a total of 1,088 acres at the average rate of 2½ cwt per acre, the cost per acre was 15/-. This cost, which covered the distribution and transport of the fertilizer over distances varying from 5 to 35 miles, is comparable with costs by normal methods on difficult country. On inaccessible hill country the cost is much less than with other methods.

AERIAL TOPDRESSING DEMONSTRATION AT OHARIU, WELLINGTON

After the success of the large scale trials in the Wairarapa, it was thought desirable to arrange a demonstration in the neighbourhood of Wellington. The Ohariu Valley area was selected and the topdressing was carried out with two Grumman Avenger aircraft operated from Paraparaumu aerodrome, 15 miles distant.

The trial demonstrated effectively the possibilities of the new method of topdressing.

FIG. 3.—Catcher for sampling and "catch."

MEASUREMENT OF DISTRIBUTION OF FERTILIZER AT OHAKEA

The Soil Conservation Council arranged for the Department of Agriculture to measure on a field scale the ground distribution of fertilizer on 48 acres at Ohakea aerodrome. Ten rows of samplers, each containing 11 catchers, were placed five chains apart across the line of flight; fertilizer was also swept from the tarmac which bounded the trial area on two sides. Conditions were ideal and only a slight wind developed during the trial. The Avenger aircraft, which was directed by radio from a ground-control operator, made five runs two chains apart dropping one ton on each occasion from a height of 400 ft. Miller[2] made a statistical analysis of the distribution which indicated that the general mean was 2.65 cwt per acre. It was also shown that, if the distance between parallel runs had been 75 ft and the rate of discharge from the hopper reduced to four-sevenths of the original rate, an almost perfect distribution would have been achieved.

It had not been realized at the time of the trials that the modified hopper discharged at such a rate that flights could be made at heights greater than 400 ft and give the required coverage in two-chain swathes. This new figure of 75 ft at a height of 400 ft, however, does agree reasonably well with the 90 ft evolved during preliminary trials.[1]

ORGANIZATION OF RESEARCH PROGRAMME

The Advisory and Co-ordinating Committee on the aerial distribution of fertilizer and seeds has investigated through its sub-committees many related aspects of the problems and has reported its findings to the Soil Conservation Council.

Aviation Aspects

The original investigations that resulted in the design and successful operation of equipment for aerial topdressing have been followed up by the R.N.Z.A.F. Once it was established that the aeroplane could be used effectively, the performance of various types of aircraft was investigated, and it was found that each type had an optimum range of efficiency. Thus, there was scope for heavy and light aircraft, operating on different classes of country, at varying distances from their bases and using different techniques of distribution. The major task of transporting fertilizer over distances up to 50 miles from base and catering for large blocks of inaccessible land was found to require large transport aircraft carrying 6- to 10-ton loads. Such aircraft require large aerodromes and a large establishment beyond the capacity of private resources to-day, but within the capacity of the R.N.Z.A.F. The performances of modern freighters (Bristol) and long range transports (Hastings) have been closely examined, while the manufacturers have undertaken complementary investigation with the object of using their aircraft for topdressing. (Fig. 4.)

The performance of helicopters has likewise been under review for seed-sowing and the committee proposes to have trials undertaken as soon as one is available in this country.

As light aircraft are the only types available in quantity in this country, their performance was investigated and Gibson[4] made a critical examination of the relative costs of distributing fertilizer on the farm; he found that within a radius of up to five miles from the farm gate, the light aircraft was 160 times more efficient than a packman, 48 times more efficient than a pack-horse, and 24 times more

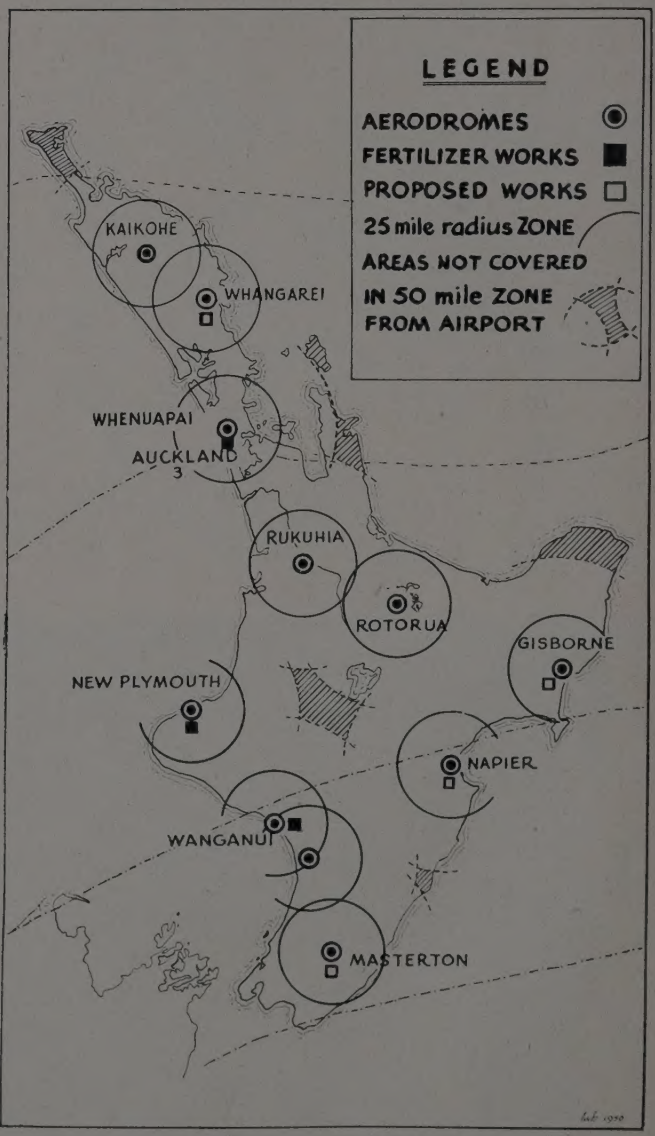

FIG. 4.—North Island Aerodromes and Fertilizer Works.

efficient than a sledge. He showed that by operating over short distances from the farm landing-strip the small aeroplane could distribute fertilizer at a rate of 2 cwt per acre for a cost of less than 10/- per acre.

Gibson and Hudson in a second paper[5] have made a critical study of performance of aircraft under New Zealand conditions and have shown the economic possibilities of using various aircraft for topdressing.

Establishment of Research and Demonstration Flight

The R.N.Z.A.F. has established at Ardmore a Research and Demonstration Flight, which is working in close association with the Engineering School at the Auckland University College. The ballistics of fertilizer particles and pasture seeds have been investigated in a vertical wind tunnel and their terminal velocities have been determined. The results are indicated in Table I:—

TABLE I. TERMINAL VELOCITIES OF SUPERPHOSPHATE PARTICLES AND SEEDS DROPPED FROM AIRCRAFT

	Terminal Velocity (Ft per Sec.)
(a) Superphosphate Particles.	
Held on ¼-in mesh	45
Passing through ¼-in mesh but held on 6-mesh screen	38.2
Passing through 6-mesh screen	33.2
(b) Seeds.	
Subterranean clover	29
Red clover	19.8
White clover	16.1
Lotus Major	14.0
Chewings Fescue	11.4
Perennial Ryegrass	11.4
Crested Dogstail	9.9
Cocksfoot	8.1
Yarrow	5.6
Browntop	2.4

Investigations are being carried out with a view to modifying the fertilizer distributing equipment, by the use of an air scoop which will impart initial lateral velocity to fertilizer particles. These particles drop from the hopper into the air blast travelling at right angles to the line of flight of the aircraft, thereby giving a wider distribution. The ballistics of particles of various shapes and of graded sizes are also being studied with the object of improving the width of spread of the fertilizer dropped.

Design of Aircraft

For efficient use in aerial topdressing the aircraft must be specially designed to facilitate rapid loading. A modern type of freight aircraft, such as the Bristol Freighter, possesses many of the required features and could possibly be suitably modified for the purpose. In view of the cost involved, however, it is unlikely that such re-design would be entertained at the present time; consequently, existing types will have to be used for a number of years. Apart from the war-time heavy bomber, which is expensive and difficult to maintain, the only two types which appear suitable are the Bristol Freighter and the Handley-Page Hastings. The former can carry six tons of fertilizer in a hopper installed within the fuselage, but modifications would be necessary to permit discharge through the floor. Such an aircraft could be used from the majority of existing aerodromes. The Hastings can carry ten tons of fertilizer in a specially constructed pod under the fuselage. With both types of aircraft their general utility would not be impaired by these adaptations.

Agricultural Aspects

The Soil Conservation and Rivers Control Council's chief responsibility under the Act is to promote soil conservation, mitigate soil erosion and prevent damage by floods. This entails comprehensive conservation management of the steeper hill country which constitutes the greater proportion of most catchments in New Zealand.

The key to conservation management is topdressing with phosphate to rebuild fertility and improve pastures, restore stability of the soil and reduce run-off.

Surveys have indicated the inadequacy of present equipment to topdress the greater proportion of this type of country on account of inaccessibility, high costs and shortage of labour.

The magnitude of the task of topdressing responsive hill country was indicated by soil surveys carried out by the Soil Bureau of the Department of Scientific and Industrial Research. Dr. L. I. Grange, Director of the Bureau, estimated that the area of such land was ten million acres. (Fig. 5.)

The response to phosphatic fertilizer has been well established and increases in carrying capacity varying from one sheep to as high as three sheep per acre have been recorded.

However, as response is so often conditioned by the clover content of pastures, the introduction of clovers and other legumes is an important aspect of the efficient use of phosphate. Accordingly, the Committee has taken up with the appropriate authorities the matter of extensive investigations into the improvement of hill country pastures. Already it is recommended that subterranean and white clover be sown during topdressing in the autumn. The role of *Lotus major, L. angustissimus, L. hispidus, Trifolium minor,* and strawberry clover in building up the nitrogen balance of the poorer hill country soils is also being investigated.

Condition of Fertilizer

As there is little variation in the terminal velocities of particles ranging from 2- to 9-mm diameter, the recommended size of fertilizer granules is 2-mm diameter. It has also been shown that discrete granules which are hard and rigid have definite advantages over the loosely cemented particles of double screened superphosphate used to date. Further investigation of the merits of using particles of various sizes is being undertaken because of its importance in the technique used by light aircraft which fly across wind to use the dispersive effect of the wind.

Improvement in fertilizer manufacture has also been examined, with a view to getting a more concentrated product. Metson[6] has reported on the "wet" and the "fusion" processes used overseas in the manufacture of phosphate.

Economics of Aerial Topdressing

The physical advantages of aerial topdressing are emphasized by the high proportion of broken hilly farming land that is too rough for mechanical transport and distributing equipment (other than primitive methods of packing and hand sowing). Hill-country topdressing is in consequence costly in money and labour. The physical factors adversely affect transport over indifferent roads and admit of little reduction in costs, while it is equally difficult to reduce the costs of sledging, packing and hand-sowing on the farm.

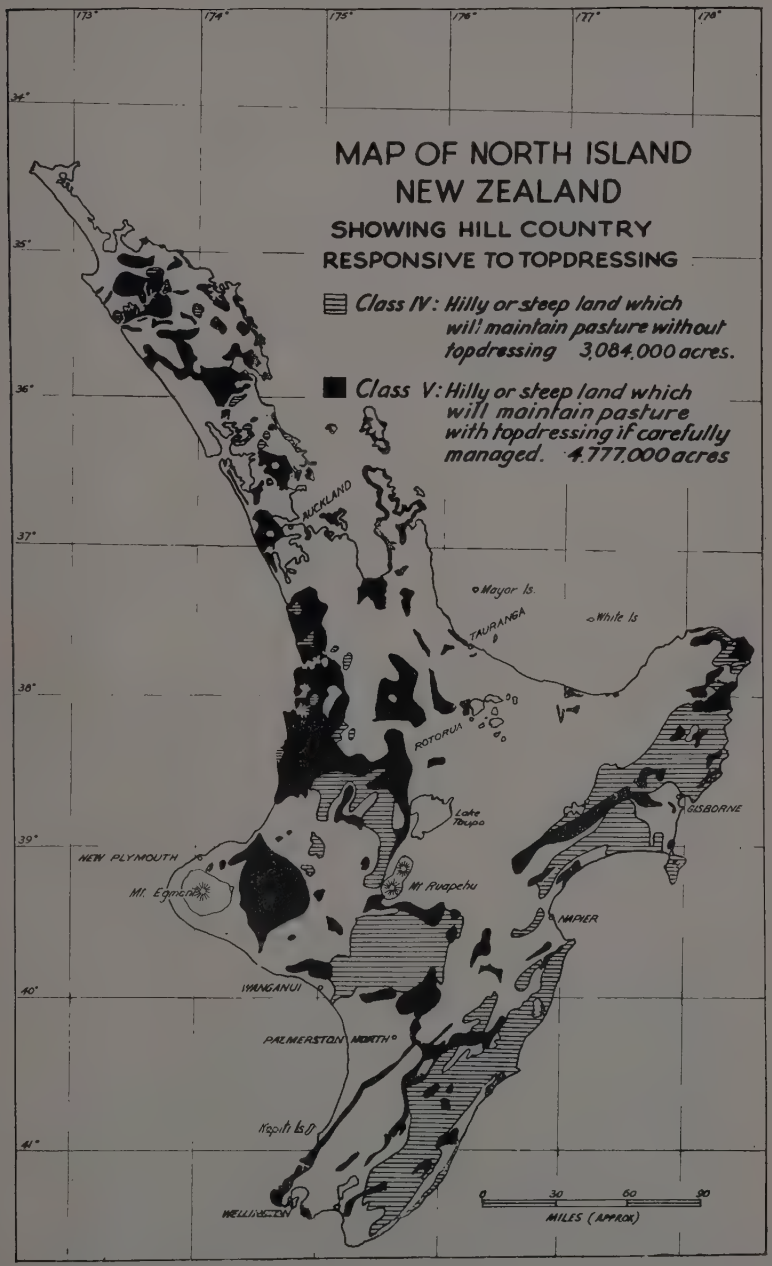

FIG. 5.—Map of North Island showing hill country responsive to phosphate.

The fact that in aerial topdressing, transport and distribution are catered for in the one operation outweighs the following disadvantages: variable weather conditions; need for increased maintenance on short flights because of frequent take-offs and landings; risk of corrosion of metallic parts; and the need for small ground-control parties, when large aircraft are used.

The approximate cost of the various methods of transport in August 1949 was as follows:—

Method of Transport.	Cost per ton-mile.
Road	2/2½d.
Rail	10d. to 1/-
Air	1/- to 6/-

The cost of air freight decreases with increase in the size of the aircraft which is in turn limited by operational considerations. The cost of operating a one-ton Avenger transport in the Wairarapa trials averaged 15/- per acre for 2½ cwt per acre applied. There are good reasons for considering this figure a high one, as costing investigations made ([3], [4] and [6]) show that the aircraft was not only obsolete and costly to operate but that it was not operated within its range of optimum efficiency.

There is every reason to believe that over the bulk of hill country aerial topdressing will compete with any other method on an overall cost basis, while on the appreciable proportion of inaccessible land there is virtually no other practicable method. As the cost of topdressing by normal methods varies from 3/6 per acre for easy country to 12/- per acre for difficult but accessible country, the prospects of using freighter aircraft such as the Bristol which has been costed at 8/- per acre up to a radius of 25 miles from the aerodrome and 14/- per acre (both 2 cwt per acre) up to 50 miles from the aerodrome are good. On the other hand light aircraft are at present being used at costs varying from 6/- to 10/- per acre for 2-cwt applications at a range of one to two miles. If double superphosphate, now available overseas, could be imported these costs would be correspondingly reduced.

Organization and Financing of Aerial Topdressing

Information and any assistance possible has been made freely available to private operators, Federated Farmers and Catchment Boards. The fringes of the hill country adjacent to landing strips are being topdressed directly by private operators at contract rates. However, organization is required for large scale topdressing of the more remote hill country with large aircraft. Much of this land can bear the cost of topdressing but large areas are marginal and eroded and justify assistance by way of subsidy for soil conservation purposes. Under the procedure being adopted, groups of farmers through their own organization, the Federated Farmers of New Zealand (Inc.), may approach the local regional authority responsible for soil conservation, the Catchment Board, to formulate proposals for a topdressing service. The Catchment Board in turn may have the land classified and forward proposals to the Council for assistance by way of subsidy on the eroded and marginal land. The Council in turn will, it is hoped, be able to arrange with the R.N.Z.A.F. to carry out the project, which the Catchment Board pays for directly. To finance the operation the Catchment Board may raise a loan for which it may subsequently recover from the farmers by rating over a period.

Topdressing Service by Light Aircraft

The successful outcome of the foregoing trials and investigations has stimulated private commercial interests to such an extent that three private operators have designed equipment for use on small aircraft. The operators have fitted suitable hoppers and have already topdressed thousands of acres of hill country adjacent to their headquarters at Auckland, Gisborne and Christchurch. They have contracted direct with the farmer and are securing more business than they can handle at a cost to the farmer of from 6/- to 10/- per acre for distributing fertilizer from the local landing strip. The planes operate from improvized grassed strips up to 300 yd in length and carry 3-5 cwt per trip (Fig. 6).

Rapid re-filling of the hopper is essential and equipment has been fashioned to do this expeditiously in a few seconds; so that the complete round trip has been reduced to less than three minutes by one operator. Under these conditions 55 tons were distributed in 9 hours on hill country within a mile radius of the landing strip. The cost under these conditions was 6/- per acre topdressed at the rate of 2 cwt of fertilizer per acre.

On the basis of 1,000 operating hours per annum each machine has a capacity of from 2,000 to 3,000 tons sufficient for 20,000 to 30,000 acres. As there are ten machines in service at present the potential annual capacity is approximately a quarter of a million acres, which means that three-quarters of a million acres can be covered on the basis of one application every three years. Private operators with small aircraft have evolved a special " cross wind " technique, by commencing on the windward side of the paddock and thus obtaining the useful dispersive effect of the moderate wind by flying at a height of 50 ft.

A further advantage of this method is that normal commercial superphosphate is used, thereby obviating the difficulty of obtaining hillside superphosphate. An experienced pilot is able to estimate the width between successive flights, viz. approximately ten yards, and to check regularly the proportion of the job done against the fertilizer used; this obviates the need for ground markings of any kind.

FIG. 6.—Hopper designed for rapid loading of aircraft.

CONCLUSIONS

The role of aircraft in farming has been established and the range of operating efficiency of light and heavy aircraft shown to be complementary. The conservation needs of the pastoral hill country can be met by aerial topdressing with phosphate coupled with prudent management. Both are essential in restoring the economic balance of the pastoral industry which depends so largely on the adequate production of store stock.

The seven-fold increase in butter, twenty-fold increase in cheese and the three-fold increase in meat production in New Zealand over the past forty years, largely due to improvement of the seven million acres of ploughable land, is the best measure of the response of pastures to phosphate topdressing.

Since there are upwards of ten million acres of responsive hill country that can now be topdressed, the possible boost to primary production is very considerable, being the equivalent of a 50 per cent increase in sheep population.

These investigations have already led to the establishment of an aerial topdressing service by private operators of light aircraft, but to cater for the Soil Conservation Council's objective of upwards of a million acres annually, a squadron of heavy aircraft would be required. This would be beyond the resources of private enterprise but could with advantage, be integrated into the activities of the R.N.Z.A.F. Transport Squadron which could serve the dual peace-time role of productive topdressing and training for defence purposes.

ACKNOWLEDGMENT

The writer gratefully acknowledges the enthusiastic team work of the members of the Advisory and Co-ordinating Committee of the Soil Conservation Council which has made this progress possible.

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BORON, COPPER, MANGANESE AND ZINC IN THE NUTRITION OF THE RED ANTWERP RASPBERRY

By H. O. Askew, E. T. Chittenden and Joyce Watson,
Cawthron Institute, Nelson, New Zealand

(*Received for publication, 9 October 1950.*)

Summary

At Motupiko favourable responses of the Red Antwerp raspberry to treatment with borax, and copper and manganese sulphates were obtained in field trials. Zinc sulphate, in the amount used, appeared to be toxic to the plants.

Except for boron, the minor element content of leaves and fruit was altered very little by the treatments applied. Use of any given minor element had little effect on the intake of the others or of major nutrient elements.

Data are also reported for samples obtained from a number of raspberry gardens in the Nelson district.

In the leaves, in the absence of treatment by the element concerned, the boron content ranged from 13 to 81 p.p.m., copper from 4 to 42 p.p.m., zinc from 6 to 54 p.p.m. and manganese from 30 to 550 p.p.m., all expressed on the dry matter basis.

Some effects of the use of minor elements on the chemical composition of the fruit were noted.

Further work is required to define more closely the conditions governing the intake of copper, zinc, and particularly manganese, by the raspberry.

Introduction

Varieties of red raspberry do not appear to have attracted much attention from workers whose interests lie in the field of minor elements, although the nutrition of the raspberry by major elements has been extensively studied. A description has been given elsewhere of the effects of boron deficiency and of fertilization with borax on the Red Antwerp variety of raspberry[1] so that discussion of boron content will be confined in the present paper to the effect of applications of borax on the copper, manganese and zinc contents of leaves and fruit.

Harris[2] applied the sulphates of copper, manganese and zinc at the rates of 30 lb, 50 lb and 15 lb per acre respectively to the Cuthbert variety grown in British Columbia. He reported the effects of these fertilizers on the dry matter and total carbohydrate contents of the berries, finding significant increases with manganese and zinc for these constituents, but not with copper. No analytical data for minor element contents of the berries were given however.

Powers and Wood[3] used zinc sulphate every second year at 30 lb per acre and obtained an increase in yield with red, but not with black, raspberries. No analytical data were reported.

Experimental

The area of Red Antwerp raspberries, the variety with which this investigation was mainly concerned, was situated on the Motupiko fine sandy loam soil type; the soil of the particular garden had a pH value of 6.9-7.2 at the depth of 0-9 in and of 6.4-6.6 at the depth of 9-18 in. The garden was nine years old when the trial was commenced.

As reported already[1] deficiency of minor elements was suspected as the cause of poor growth in this garden.

An area was laid out in plots of seven bushes, four replications being provided for the following treatments: No minor elements; Borax, ½ oz per bush; copper, zinc, and manganese sulphates each at 1 oz per bush; and a treatment combining these four chemicals at the above rates. In addition, two replications were set out combining borax and copper sulphate, and zinc and manganese sulphates at these rates. The chemicals were placed close around the bases of the bushes. No guard rows were left between the various treatments when the bushes were treated on 8 September 1947. At a planting rate of 1200 bushes per acre the ½ oz and 1 oz rates correspond to 37.5 lb and 75 lb per acre. A complete N-P-K fertilizer was used on all plots. In the following season no

FIG. 1.—No minor elements, photographed 23.12.48.

further soil applications were made, but the minor elements were supplied as sprays compounded as follows:—

Borax: 5 lb per 100 gal of water.
Copper: 10 lb $CuSO_4.5H_2O$ plus 5 lb hydrated lime per 100 gal of water.
Manganese: same quantities as for copper.
Zinc: same quantities as for copper.

The treatments combining two or more chemicals were not repeated. Application of the above sprays was made on 15 November 1948, sufficient of the liquid being used to completely drench the plants. No leaf injury followed the use of these sprays.

On 2 November 1949 the same mixtures as for 1948 were used and in addition the borax plus copper, zinc plus manganese, and the complete mixture (less zinc) were applied, lime being added as in the single element sprays.

FIG. 2.—Borax treatment, photographed 23.12.48.

RESULTS

Field Observations

It has already been reported[1] that the bushes showed a distinct response to borax. There was also a definite improvement in growth following the use of copper alone or in combination with borax. In December 1947, between three and four months after the soil applications had been made, some of these responses were visible, but the good growing conditions of that season reduced the differences between treatments that might otherwise have been apparent. These distinctions were still apparent at the end of February 1948 and in addition there was an indication that zinc had caused a deterioration in the condition of the bushes.

FIG. 3.—Copper sulphate treatment, photographed 23.12.48.

At the date of the first applications of sprays in November 1948, favourable responses to boron, boron plus copper, and the complete four-element mixture were seen. Copper was beneficial and manganese possibly beneficial, but zinc was unsatisfactory. Control (no treatment) bushes were in a very poor condition. Figs. 1-4 show the condition of representative bushes on 23 December 1948. By February 1949 the zinc-treated plots were in a worse condition than those receiving no minor elements, the plants on both plots lacking growth and vigour. All boron-treated plots showed improved growth as did those receiving manganese. Copper used alone was the most outstanding treatment, the bushes having held their foliage in better condition than the others. In addition, growth was stronger. The combined boron-plus-copper treatment was satisfactory, being slightly better than that using the four elements. Zinc-plus-manganese treated plots were generally poorer than most of the plots but were better than the zinc or the untreated plots.

FIG. 4.—Borax plus copper sulphate treatment, photographed 23.12.48.

Towards the end of March the copper treatments were still very noticeable for the manner in which the bushes had retained the leaves on the old canes. By this time bushes on other treatments, except some receiving manganese, had lost most of these leaves. The zinc treatments were marked by the relatively poor new cane growth, whereas copper was very satisfactory in this respect. Manganese treatment also had developed satisfactory new cane growth. Boron, however, did not show up so well at the end of the season as it did earlier. Combined treatments containing copper and manganese were beneficial to new cane growth.

In the 1949-50 season the results were very similar to those of the 1948-49 season reported in detail above. Again the most outstanding results were obtained with any treatment containing boron and/or copper. Boron was particularly effective in the early part of the season (October-November), and copper at the end. Manganese was again beneficial but not to the same extent as boron or copper. Zinc was still apparently toxic, because plots receiving this element were generally worse than those receiving no treatment. It is possible that the original soil application of 75 lb of zinc sulphate per acre was excessive and that this had not yet been leached out of the root zone of the plants. Harris[2] used only 15 lb, and Powers and Wood[3] 30 lb of zinc sulphate per acre. No harmful effects from these quantities were reported.

On an area at Rakau, on Motupiko fine sandy loam, copper sulphate has been applied for two seasons in succession at the rate of 1 oz per bush, but up to the present no response has been noted.

Laboratory Investigations

Leaf samples have been taken on several occasions from the field plots for determination of their boron, copper, manganese and zinc contents. Samples were taken from lateral growth on both old (fruiting) and new canes by removing the first mature leaf, usually the fourth, counting from the tip of the shoot. After drying, the material was ground by rubbing through the hands to prevent any possibility of metallic contamination from the use of mechanical mills. Boron was determined by the method of Maunsell[4] with the modification of adding quinalizarin to the sulphuric acid in the dispensing burette. The method of Clare, Cunningham and Perrin[5] was employed for the copper estimation. Manganese was extracted by dilute sulphuric acid from the ash and determined by the periodate method, and zinc by the method of Cholak *et al.*[6] as modified by Watson[7] for plant material.

Leaves

In Table I analytical data for samples of Red Antwerp raspberry leaves are set out. The samples cover two seasons, with two types of leaves in each season. On 8 February 1949 samples were obtained from old and new canes. As shown in Table I, the effects of the sprays applied in November 1948 in raising the level in the leaves of the constituent in the spray employed are noticeable. Although the possibility of spray residues of the metals still being present on the leaves in February cannot be excluded, it does not seem likely that such contamination would occur because of the continued growth of laterals after spraying and before sampling. For the samples from new growth, except for borax and manganese sulphate, there is little variation in minor element content due to treatment. There is evidence, however,

that copper and zinc treatment has reduced the boron intake. Since yield responses were obtained with both borax and copper sulphate, the boron and copper figures for leaves from bushes receiving no minor element treatment must be regarded as sub-normal.

In the 1949-50 season samples were obtained from old canes on 31 October 1949, before the new season's sprays were applied, and on 23 January 1950, twelve weeks after the sprays were applied. Evidence of the effectiveness of the previous borax treatments is seen in the boron contents of approximately 50-60 p.p.m. of boron in the October samples. No other treatments show consistent effects. It may be noted, however, that a boron content of up to 50 p.p.m. is probably desirable for healthy growth. After spraying, the boron content rose to 196.5 p.p.m. for borax alone, to 146.9 p.p.m. for boron plus copper, and to 128.6 p.p.m. for complete element mixture (less zinc). All the boron data of Table I suggest that the addition of copper to the borax spray, even in the presence of manganese, results in a reduced intake of boron by the plant. Zinc sulphate also causes a smaller uptake of boron. The application of sprays containing copper and zinc had no effect on the content of

TABLE I. BORON, COPPER, MANGANESE AND ZINC CONTENTS OF RED ANTWERP RASPBERRY LEAVES AT MOTUPIKO (EXPRESSED IN PARTS PER MILLION OF DRY MATTER)

Date of Sampling	Type of Cane	Treatment	Boron (p.p.m)	Copper (p.p.m)	Manganese (p.p.m)	Zinc (p.p.m)
8/2/49	Old	No minor elements	27.9	9.8	96.0	10.5
		Borax	197.8	12.8	122.8	11.4
		Copper Sulphate	53.8	337.0	128.0	6.2
		Manganese Sulphate	32.2	17.0	273.0	12.3
		Zinc Sulphate	18.2	8.6	93.6	208.0
		Borax plus Copper	137.6	43.6	162.3	12.3
		Manganese plus Zinc	23.6	7.4	94.6	11.4
		Complete	123.7	13.6	143.0	12.3
8/2/49	New	No minor elements	25.2	8.5	101.2	21.1
		Borax	79.3	12.8	115.0	17.0
		Copper Sulphate	17.9	15.4	95.4	20.0
		Manganese Sulphate	16.7	16.5	143.3	13.7
		Zinc Sulphate	14.9	14.6	103.4	20.2
		Borax plus Copper	50.6	12.0	117.6	20.3
		Manganese plus Zinc	17.4	10.7	104.2	21.0
		Complete	58.8	10.7	142.6	19.7
31/10/49	Old	No minor elements	24.9	10.4	115.7	29.9
		Borax	60.3	10.4	90.5	20.0
		Copper Sulphate	24.8	13.1	78.8	28.0
		Manganese Sulphate	25.9	11.5	120.5	28.5
		Zinc Sulphate	24.3	16.8	93.4	39.9
		Borax plus Copper	55.6	12.0	101.6	20.1
		Manganese plus Zinc	24.9	13.9	98.8	22.2
		Complete	52.4	10.5	99.3	32.8
23/1/50	New	No minor elements	27.0	10.2	92.8	30.1
		Borax	196.5	7.7	88.2	29.1
		Copper Sulphate	29.5	10.4	79.1	29.5
		Manganese Sulphate	24.7	6.9	109.5	29.1
		Zinc Sulphate	22.9	17.4	81.7	30.3
		Borax plus Copper	146.9	19.8	96.3	28.1
		Manganese plus Zinc	19.4	13.0	104.0	30.0
		Complete less-Zinc	128.6	15.1	92.4	32.0

these elements in the leaves. The increased contents of manganese in the January samples where manganese sprays were used are not large and may not be significant. Interactions of one metal on the intakes of other metals are not apparent, such differences in the contents of particular elements as are shown in Table I being probably due to experimental errors.

In keeping with the lack of response to soil applications of copper sulphate at Rakau, the analytical data for leaf samples taken on two occasions showed no increase in copper content for the treated bushes; neither were there any consistent variations in the zinc and manganese contents.

Samples of leaves from experimental plots at Rakau, already analysed for boron content, were available for copper, manganese and zinc determinations. These samples were derived from plots receiving ½ oz and 1 oz of borax per bush, and 8 cwt of dolomite and 10 cwt of magnesium sulphate per acre. Table II contains the full analytical data for these samples. The magnesium applications appear to have had no consistent effect on the level of any of the constituents reported, although dolomite tended to reduce the boron content. Borax has not affected the level of the copper, manganese and zinc contents. The level of copper is generally lower than at Motupiko. Manganese at 45 to 90 p.p.m. is also lower, due no doubt to the high pH value of 7.4 for the Rakau area. The zinc content however is higher in the February 1948 samples than at Motupiko, but is at about the same level for the 1949-50 samples.

TABLE II. BORON, COPPER, MANGANESE AND ZINC CONTENTS OF RED ANTWERP RASPBERRY LEAVES AT RAKAU (EXPRESSED IN PARTS PER MILLION OF DRY MATTER)

Date of Sampling	Type of Cane	Treatment	Boron (p.p.m)	Copper (p.p.m)	Manganese (p.p.m)	Zinc (p.p.m)
8/2/49	New	No minor elements	16.8	7.9	46.2	17.3
		Borax ½ oz	52.5	6.1	48.9	26.6
		Borax 1 oz	61.4	6.9	56.1	31.1
		Magnesium Sulphate	12.9	7.7	45.2	23.3
		Dolomite	13.4	8.5	50.2	25.4
8/2/49	Old	No minor elements	20.8	10.3	48.0	24.8
		Borax ½ oz	123.8	4.9	47.7	27.1
		Borax 1 oz	124.9	9.7	51.0	20.4
		Magnesium Sulphate	22.3	5.4	37.7	20.1
		Dolomite	22.3	8.4	30.6	21.7
7/12/49	Old	No minor elements	20.9	28.5	75.0	30.0
		Borax ½ oz	47.8	41.7	68.3	29.8
		Borax 1 oz	58.4	26.0	81.5	25.2
23/1/50	New	No minor elements	22.3	4.8	77.9	27.8
		Borax ½ oz	95.2	6.7	88.5	31.5
		Borax 1 oz	144.4	6.7	72.1	30.6
		Magnesium Sulphate	37.5	8.4	71.3	28.5
		Dolomite	17.3	6.7	62.9	27.8

Opportunity has been taken to analyse for copper, manganese and zinc contents the series of leaf samples from growers' gardens taken in connection with the boron investigation already reported.[1] Data for these samples, set out in Table III include also the pH value of the soil of some of the gardens.

TABLE III. BORON, COPPER, MANGANESE AND ZINC CONTENTS OF RED ANTWERP RASPBERRY LEAVES, WITH AND WITHOUT BORAX TREATMENT.

Date of Sampling	Type of Cane	Treatment	Boron (p.p.m.)	Copper (p.p.m.)	Manganese (p.p.m.)	Zinc (p.p.m.)
8/2/49	New *	No borax	24.9	6.9	239.3	23.8
"	"	Borax	51.9	4.2	227.1	33.9
28/11/49	Old	No borax	26.0	11.3	202.6	29.8
"	"	Borax	70.0	8.1	130.9	38.4
24/1/50	New	No borax	60.4	17.7	176.7	28.0
"	"	Borax	110.5	6.9	205.8	24.1
4/4/49	New	No borax	38.2	12.5	200.0	15.4
7/12/49	Old *	Borax	40.1	-	140.8	37.7
27/1/50	New	"	76.7	19.6	168.6	27.2
7/12/49	Old *	Borax	51.6	13.6	238.7	53.8
27/1/50	New	Borax	131.9	11.5	452.0	28.6
8/2/49	New *	No borax	13.0	9.6	71.8	39.4
7/12/49	New	No borax	21.5	15.4	94.7	38.1
"	"	Borax	38.4	12.1	120.2	49.5
7/12/49	Old	No borax	28.2	12.5	213.3	38.1
4/4/49	New	No borax	44.0	10.3	96.4	16.6
28/11/49	Old	"	38.6	11.8	75.5	48.9
28/11/49	Old	No borax	27.4	108.7	117.0	40.1
"	"	Borax	84.1	145.1	209.5	41.0
27/1/50	New	No borax	56.5	12.6	299.6	34.9
"	"	Borax	189.3	12.4	224.3	33.3
28/11/49	Old *	No borax	23.0	80.6	261.5	42.1
"	"	Borax	104.0	226.3	164.1	37.2
27/1/50	New	No borax	37.4	13.1	202.0	27.1
"	"	Borax	221.9	12.4	549.9	30.0
8/2/49	New *	No borax	55.3	9.6	449.5	50.4
"	"	Borax	153.6	9.6	319.2	19.2
28/11/49	Old	No borax	41.6	69.0	536.6	47.6
"	"	Borax	65.1	79.4	287.3	49.8
27/1/50	New	No borax	38.2	13.4	460.6	36.5
"	"	Borax	164.1	13.1	276.3	36.3
28/11/49	Old	Borax	143.4	1113.5	237.7	36.2
27/1/50	New	Borax	130.3	13.7	480.4	28.0
28/11/49	Old	No borax	31.8	10.0	85.5	54.2
27/1/50	New	"	50.1	26.4	385.1	28.1
4/4/49	New *	No borax	28.5	7.4	54.0	13.9
7/12/49	Old	"	24.5	8.6	148.2	29.5
27/1/50	New	"	56.8	11.5	275.6	28.2
4/4/49	New	No borax	33.5	8.7	185.6	16.2
7/12/49	Old	"	23.1	9.1	145.4	37.0
27/1/50	New	"	49.6	14.1	448.4	26.8
4/4/49	New *	No borax	22.9	7.6	201.1	18.5
28/11/49	Old	No borax	40.6	21.2	236.8	47.8
"	"	Borax	85.2	32.1	215.6	47.7
23/1/50	New	No borax	81.0	10.0	270.0	27.1
"	"	Borax	127.2	10.4	202.5	30.2

* With these canes pH values of the adjacent soil were taken at depths of 0 to 9 in; these ranged from 5.0 to 6.3.

The first five gardens reported in Table III are located on soils derived from granite. On these areas the use of borax appears to have decreased the copper but increased the zinc intake, while no consistent effect has been exerted on the level of manganese. Nearly all the remaining gardens are situated on the Motupiko fine sandy loam or sandy loam soil types. Considerable differences in the levels of copper, zinc and manganese are shown. Copper figures of the order of 100 p.p.m. or more are undoubtedly due to the use of copper sprays by the growers concerned. Generally the copper content is 10-14 p.p.m. with an occasional sample giving as high as 32 p.p.m. On these soil types borax applications have not had any consistent effect on the level of copper in

the leaves. Zinc content has ranged from 14 to 50 p.p.m., with the most common values at 30-40 p.p.m. Borax has not influenced the zinc content of the leaves from bushes grown on the Motupiko soil types. Manganese has varied widely from 54 to 550 p.p.m., but only a few values are greater than 300 p.p.m. Most of the values lie between 200 and 300 p.p.m. In seven out of nine comparisons the use of borax has resulted in a reduction of the manganese figure, in some cases slightly, in others appreciably. The highest manganese values tend to occur with leaves from new growth. Low pH value of the soil tends also to high manganese contents of the leaves.

Determinations of soluble ash, lime, magnesia, potash, phosphoric acid and nitrogen contents of leaves from old and new canes at Motupiko sampled on 8 February and from old canes on 31 October 1949 did not indicate that the use of copper, manganese or zinc had had any appreciable or consistent effect on the levels of the major constituents in the dry matter of the leaves, although there were large differences in mineral content between leaves from the two types of cane growth.

Canes

Samples of new canes were obtained from the experimental plots at Motupiko at the end of the 1949-50 season, namely, on 13 June. The canes were cut about 6 in from the ground and then the lower 3 ft of the canes was taken for the samples. Determinations of the boron, copper, manganese and zinc contents are reported in Table IV, where the data are expressed as parts per million of the element in the dry matter.

TABLE IV. MINOR ELEMENTS IN NEW-GROWTH RASPBERRY CANES
(EXPRESSED IN PARTS PER MILLION ON THE DRY MATTER BASIS)

Treatment	Boron	Copper	Manganese	Zinc
No minor elements	9.7	4.6	20.1	9.7
Copper Sulphate	11.2	7.4	21.5	11.7
Manganese Sulphate	8.7	5.6	27.0	12.3
Zinc Sulphate	7.5	8.0	20.2	20.6
Borax	23.9	4.2	18.3	9.3
Borax + Copper	20.8	10.0	18.5	9.1
Manganese + Zinc	11.3	7.6	25.4	20.0
Complete less Zinc	18.7	8.3	20.5	19.9

A specified minor element has been increased in the canes following the use of a spray containing it, but the most marked effects have been obtained with those sprays containing borax. The response to zinc has been somewhat greater than with copper and manganese. It is notable too that the manganese content of canes is strikingly lower than that of leaves.

Two samples of fruiting canes from Rakau taken on 4 April 1949 gave the following contents of minor elements for untreated bushes and those receiving ½ oz of borax per bush:—

Treatment	Boron (p.p.m.)	Copper (p.p.m.)	Manganese (p.p.m.)	Zinc (p.p.m.)
No borax	6.2	9.6	27.1	5.2
Borax ½ oz per bush	10.0	4.7	20.7	4.1

Borax has again been effective in raising the boron content of the canes and would appear to have depressed the copper and manganese contents. Zinc is much lower than at Motupiko but the copper and manganese contents are at about the same level at each location. As no data for the minor element contents of raspberry canes have been found in the literature, it is not possible to state whether the minor element levels found in the present analyses are normal or not. In view of the responses obtained from the use of the minor elements at Motupiko and Rakau some at least of the four elements reported above are probably present in sub-optimal amounts.

Fruit

On 17 January 1949 fruit samples were obtained from the plots at Motupiko. Data for the minor element content, in parts per million on the dry basis, for the dry matter content and the sugars contents on the fresh fruit and for the pH value of the pulped fruit are set out in Table V.

Borax and zinc sulphate have increased the dry matter content of the fruit, but their effects have been reduced when used in combination with copper sulphate and manganese sulphate respectively; these combination treatments have however given appreciable increases in dry matter content. Copper and manganese sulphates used by themselves did not affect the dry matter content. Harris[2] found that boron, manganese and zinc applications significantly increased the dry matter content of the red Cuthbert raspberry. He also found that the last two elements significantly increased the carbohydrate content of the fruit; boron increased it also, but barely significantly. The data of Table IV show that any treatment containing boron and the zinc-plus-manganese treatment increased the content of sugars of the Red Antwerp variety. Copper, zinc and manganese sulphates used singly did not appreciably increase the sugar figures. No treatment has affected the pH value of the pulped fruit.

Any treatment containing borax has doubled the boron content of the fruit. No recent data for the boron content of raspberry fruits have been found in the literature available, so that it is not known what is a normal figure for this constituent. The copper figures are irregular and suggest that in certain cases contamination of the samples had occurred. Beeson[8] quotes the value 8 p.p.m. for copper in raspberry fruits, while McCance *et al.*[9] give an average figure from three samples of Kentish raspberries which, when calculated to the dry matter basis, corresponds to 12 p.p.m. The treatments containing copper have raised the copper content of the Nelson fruit to the latter level. Improved growth following treatment with borax may have enabled the plants to obtain copper sufficient to raise the content of this constituent to the figure given in Table IV. Manganese has been slightly increased by the use of manganese sulphate, alone or in combination with zinc. The level of 20-30 p.p.m. in the Nelson fruit may be compared with the figure of 46 p.p.m. quoted by Beeson[8]. Monier-Williams[10] has included raspberries in the group of foods containing 10 to 50 p.p.m. of manganese in the fresh material. Even the lower figure would give a value of at least 75 p.p.m. on the dry matter basis. Borax and manganese sulphate sprays appear to have reduced the zinc content of the berries while zinc sulphate has increased it appreciably. The high figures for zinc content

of fruit from the borax plus copper sulphate and zinc plus manganese sulphates are probably due to contamination. Monier-Williams[10], includes raspberries in a class of foods containing 2 to 8 p.p.m. of zinc in the fresh material. This would correspond to a dry matter content of 15 to 60 p.p.m. approximately. The data for the Nelson samples would thus be in the lower end of this range.

Determination of the soluble ash, lime, magnesia, potash, and phosphoric acid contents did not reveal any important variations in the composition of the dry matter due to the minor element treatments. The average figures, in percentages of the dry matter, were respectively: 2.93, 0.37, 0.27, 1.25 and 0.53.

Discussion

The experimental work reported in this paper suggests that in raspberry gardens where a generous liming programme has been carried out fertilization with copper, and possibly with manganese, may prove beneficial to the growth of the Red Antwerp variety. At the present time no information is available as to any probable effect of these elements on the nutrition of other varieties. In respect of copper the issue is not clear-cut even with the Red Antwerp variety. Fungous diseases are present in the experimental gardens, and until these are brought under satisfactory control by means other than the use of Bordeaux mixture the true position of copper in the nutrition of the raspberries cannot be evaluated. Future work will be directed to this end. It is true that responses were obtained from the soil applications of copper and manganese but the subsequent use of these elements in sprays has prevented positive identification of a lack of copper in the Nelson gardens. The position with manganese is more satisfactory because manganese used in spray form with lime is not likely to be an effective fungicide.

The data reported in the present paper show that, except for boron, it has been difficult to increase the minor element content of the leaves following the use of sprays containing boron, copper, manganese or zinc. On the other hand very appreciable differences in minor element content have been found for samples taken in different seasons from similar positions on the bushes. Thus with leaves from new canes, zinc contents of approximately 20 and 30 p.p.m. were found in 1949 and 1950 respectively. Manganese contents have varied widely not only from garden to garden but also for material taken at different times from a given area. Soil type, and in addition the pH value of the particular soil in question, would appear to be important in regulating the intake of manganese by the plants, but further data are required before this question can be more profitably pursued.

A survey of the available literature indicated that very little information was to be found concerning the response of raspberries to fertilization with minor elements and that no data were available for the boron, copper, manganese or zinc content of raspberry leaves under field conditions. Moreover very little work has been carried out with the raspberry in sand cultures. Corbett[11] in 1943 reported having grown black raspberry in cultures from which manganese, alone or in combination with other elements, was omitted, but did not give any account of the behaviour of the plants under these conditions. In view of this paucity of information about the nutrition of the raspberry it is proposed to carry out culture work under conditions of deficient supply of boron, copper, manganese or zinc.

TABLE V. MINOR ELEMENT, DRY MATTER AND SUGAR CONTENT AND pH VALUES OF RED ANTWERP RASPBERRY FRUITS

Treatment	Dry Matter[x] (p.p.m)	Boron (p.p.m)	Copper (p.p.m)	Manganese (p.p.m)	Zinc (p.p.m)	Reducing sugars[x] (%)	Sucrose[x] (%)	pH Value[x]
No minor elements	12.21	13.4	6.1	22.9	23.3	4.23	0.09	2.95
Borax	14.05	29.4	12.3	21.2	16.7	4.84	0.000	2.95
Copper sulphate	12.64	12.3	13.3	18.4	32.3	4.40	0.23	2.95
Zinc sulphate	13.98	11.7	7.6	20.7	52.5	4.54	0.11	2.90
Manganese sulphate	12.36	12.9	40.1	29.2	17.8	4.26	0.28	2.95
Borax + Copper sulphate *	13.33	27.3	139.0	26.9	62.7	4.95	0.00	2.95
Zinc and Manganese sulphates *	13.64	11.8	5.4	30.0	82.6	4.91	0.00	2.90
B + Cu + Zn + Mn*	12.97	25.3	17.5	23.4	24.9	4.77	0.22	2.95

x On fresh fruit.

* No spray applied in this season.

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SEED DISINFECTION

1. PRELIMINARY SELECTION OF VEGETABLE-SEED PROTECTANTS

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Summary

Out of 28 fungicides tested in glasshouse and field trials 7, viz. Cuprocide, Spergon, Panogen, TMTD, FDD, Dow 9B, and 36L, proved to be more promising than the remainder.

Although some laboratory screening tests were tried, the basis of selection was provided by soil tests.

Optimum emergence occurred at a medium moisture level, viz. 45 per cent water holding capacity.

To assess phytocidal and protectant action of materials, tests were also carried out at low and high moisture levels.

Pre-emergence damping-off occurred throughout all levels of soil moisture.

The efficiency of protectants was more marked for peas than for lettuces.

Isolations from seed and seedlings recovered from soil indicated that *Pythium, Rhizoctonia* and *Fusarium* were the pathogens mainly responsible for damping-off.

Introduction

Poor emergence of seedlings, caused by seed-borne or soil-borne organisms, is familiar to all who are concerned with the growing of plants. Numerous investigations have been made into the causes of such losses and various chemical treatments have been recommended as control measures. Consequently there is now a wide range of literature dealing with the subject and recommendations have been made for application of numerous materials.

For the purpose of selecting the most effective materials preliminary glasshouse trials were arranged. A number of subsidiary experiments of a laboratory type were also carried out but results from these were not considered to be reliable, and they are therefore dealt with in summary form only.

Materials

Tests described in this paper were carried out during 1947 and 1948, the vegetable seeds used being lettuce, variety Imperial, harvested in 1947, and pea, variety Laxton's Superb, harvested in 1946. Samples were taken by inserting a tube into the bulk of seed. Ten samples, each of 100 seeds were examined under a binocular microscope (X 25) for purity, damage, lesions and discolouration, while moisture content of seed was ascertained from the mean of 4 samples of each variety dried at 100°c. for 24 hours. Results are given in Table I.

Although both lines of seed showed substantial contamination with fungal growth such as mycelia, sclerotia and specific parasites such as *Ascochyta* on pea, they gave satisfactory germination in the laboratory, viz. 97.4 per cent for lettuce and 97.5 per cent for pea.

TABLE I. QUALITY OF SEED: DATA BASED ON 10 SAMPLES OF 100 SEEDS EACH

Condition of seeds	Percentage of seeds affected	
	Lettuce	Pea
Discoloured	1.5	1.0
Foreign bodies	5.0	1.5
Weeds	6.0	2.0
Mycelium	18.0	12.0
Sclerotia	11.0	2.5
Ascochyta (pycnidia)	-	6.0
Insect damage	-	1.0
Mechanical damage	3.0	5.0
Moisture content	7.3	12.7
Weight of 100 seeds (g)	0.147	28.84
Variability (%) ±	3.5	3.5

Altogether 28 chemical preparations of different composition were tested. These were as listed below:—

1. *Cuprous oxides*: Cuprocide (94.0 per cent red cuprous oxide), CO (85.8 per cent red cuprous oxide), Yellow Cuprocide (90.0 per cent yellow cuprous oxide), and Perenox C (72.0 per cent yellow cuprous oxide).

2. *Quinones*: Spergon (98.0 per cent tetrachloro-para-benzoquinone), Phygon (98.0 per cent 2, 3 dichloro, 1-4 naphthoquinone).

3. *Organo-mercury compounds*: Liquids: Fixtan Liquid (0.125 per cent phenyl mercury), and Panogen (0.8 per cent alkyl mercury). Dusts: Agrosan GN (1.0 per cent mercury tolyl acetate), Agranin Dispersible (2.2 per cent alcoxy-alkyl-mercury), Sanagran TN (3.0 per cent mercury), Agranin (3.7 per cent alcoxy-alkyl mercury), Fixtan (5.8 per cent phenyl mercury), Barbac (8.0 per cent mercuric phenyl cyanamide), and Calomel (84.9 per cent mercury).

4. *Derivatives of dithiocarbamic acid*: TMTD (commercially pure tetramethyl thiuram disulphide), Fernasan (50 per cent TMTD), TMTD Dispersible (containing 50 per cent of the active ingredient), Nomersan (10 per cent TMTD), TMTM (commercially pure tetramethyl thiuram monosulphide), ZDD (commercially pure zinc dimethyl dithiocarbamate), CDD (commercially pure cupric dimethyl dithiocarbamate), CPD (commercially pure cupric pentamethylene dithiocarbamate), and FDD(commercially pure ferric dimethyl dithiocarbamate).

5. *Other materials*: PEPS (40.0 per cent polyethylene polysulphide latex), PCDB (commercially pure pentachloro-dinitro-benzene), Dow 9B (50 per cent zinc-trichloro-phenate), and 36L (commercially pure nitroso pyrazole).

EXPERIMENTAL METHOD

Application of Materials to Seed

Materials were applied as percentages of seed weight. Accurate dosages of dusts or liquids were weighed or pipetted and applied to small amounts of seed; even distribution was ensured by shaking both in a conical flask for 5 minutes. Rate of application was ascertained by reweighing treated seed and by continuing treatment until the desired dosage was obtained. Small dosages of dusts were applied in dilution with talc, those of liquids with water.

Dispersible materials were not as adherent as non-dispersible and required longer mixing to ensure even coating of seed.

Laboratory Experiments

Slide germination tests:

Fungicidal tests *in vitro* were carried out with a number of dispersible materials. The effect of various dosages was tested by the slide germination technique on germination of spores of *Alternaria solani* measured by the haemocytometer method. Where necessary, the preparations were stabilized by use of a dispersing agent, Dispersol T, a commercial product. It was possible by these means to differentiate between various preparations; thus, Perenox C and PCDB inhibited germination at 100 p.p.m., Phygon at 50 p.p.m., TMTD (50 per cent D) and FDD at 25 p.p.m., and Panogen at 12.5 p.p.m. The method, however, was not pursued, largely because it was obvious that the results bore no direct relationship to the behaviour of the substances as seed protectants in soil.

Tests with pathogens in culture:

Plates of media (malt extract agar and soil extract agar as representing high and low nutritive levels respectively) were inoculated with various fungi, so that young circular colonies were established. Eight

FIG. 1.—Lettuce seed planted on malt agar inoculated with *Botrytis cinerea*. Left: untreated seed killed before it could germinate. Right: germination of seed treated with TMTD.

seeds, with or without protectant, were then planted a short distance ahead of the advancing mycelium. From the manner of growth of the cultures and germination of seed, one could then judge to what extent the materials protected seeds from attack by the pathogen concerned.

In the absence of protectants, the seed became overgrown by the fungal culture and in some cases, e.g., lettuce seed and culture of *Botrytis cinerea*, the seed was killed before it could germinate (Fig. 1). In the presence of a protectant the seed might be overgrown but nevertheless it germinated.

TABLE II. GERMINATION OF LETTUCE SEED ON MALT AGAR INOCULATED WITH SEVERAL PATHOGENS

Treatment	Mean percentage germination of lettuce seed in cultures inoculated with:			
	Alternaria solani	Rhizoctonia solani	Botrytis cinerea	Fusarium solani
Control	75.0	77.8	11.1	62.3
Cuprocide	75.0	62.3	11.1	62.3
Spergon	87.5	87.5	0.0	75.0
Panogen	62.5	87.5	0.0	50.0
TMTD	100.0	100.0	100.0	75.0
FDD	75.0	87.5	22.3	75.0
Dow 9B	75.0	74.0	33.4	87.5
36L	100.0	100.0	11.1	100.0

All materials previously listed were used in these tests, but for purpose of abbreviating the tables only substances consistently giving favourable results in the various tests are mentioned (Table II).

An interesting feature of the results given in Table II is the destructive effect of *Botrytis cinerea* on lettuce seed and the fact that certain well-known fungicides give no protection whatever against this fungus under the conditions prevailing.

TABLE III. GERMINATION OF LETTUCE AND PEA SEED ON MALT OR SOIL AGAR INOCULATED WITH PYTHIUM DE BARYANUM

No.	Treatment	Percentage Germination			
		Lettuce		Pea	
		Malt	Soil	Malt	Soil
1	Control	0.0	37.5	25.0	50.0
2	Cuprocide	22.3	50.0	80.0	100.0
3	Spergon	11.1	65.0	87.5	100.0
4	Panogen	33.4	58.5	100.0	100.0
5	TMTD	55.6	100.0	100.0	100.0
6	FDD	33.4	77.5	87.5	100.0
7	Dow 9B	0.0	49.5	75.0	75.0
8	36L	11.1	100.0	75.0	100.0

In plating tests with weak and rich media the test organism was *Pythium de Baryanum*. This organism occurred frequently in isolations from ungerminated seed and diseased seedlings from glasshouse tests. Results are given in Table III.

The effects of protectants on fungal growth and seed germination were more pronounced on the weak soil agar medium than on the rich malt medium (Fig. 2).

A definite appreciation of the value of plant protective substances by methods of this type cannot be made as conditions are far removed from those prevailing in practice. In general, although results from these tests gave good correlation with soil tests (Table IV) some of the substances, e.g., Spergon, which gave unpromising results, proved to be most useful seed protectants when tested in soil.

Plating tests:

Untreated and treated seed was placed on malt agar and a record of seed germination as well as of fungal colonies was taken after 6 to 10 days. Although fairly satisfactory in eliminating unpromising materials this method was subject to serious error. Thus, all the copper preparations were ineffective in checking fungal growth, and would be discarded on the basis of these tests, though in fact some of them, e.g., Cuprocide,

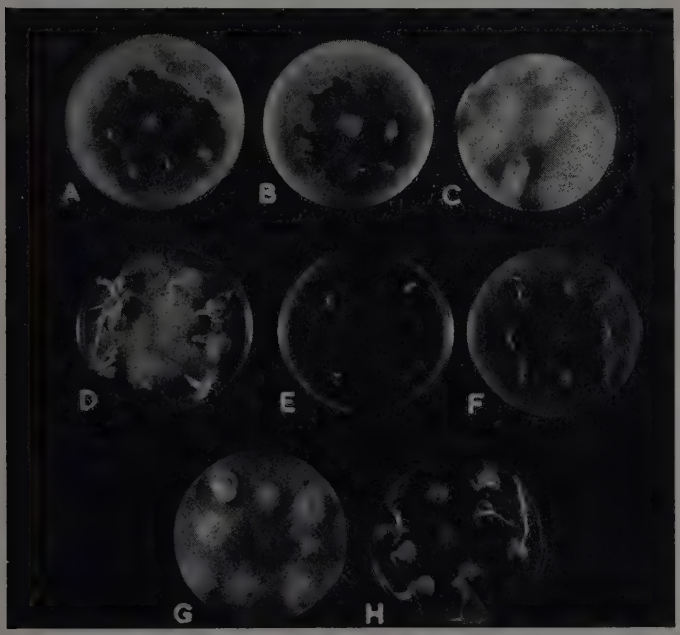

FIG. 2.—Pythium test for evaluation of seed protectants. Seed treated with TMTD used for illustration of tests. Malt agar: A untreated, B treated lettuce seed; C untreated, D treated pea seed. Soil agar: E untreated, F treated lettuce seed; G untreated, H treated pea seed.

are valuable as seed protectants. Furthermore, it was found that certain preparations of TMTD were equally effective in plating tests (Fig. 3) whereas in the more practical tests in soil, there were considerable differences between them.

Laboratory tests give some indication as to efficacy of substances in controlling certain organisms and their suitability as seed protectants. Conditions, however, are too severe for adequate comparison of results with those obtained from glasshouse and field trials.

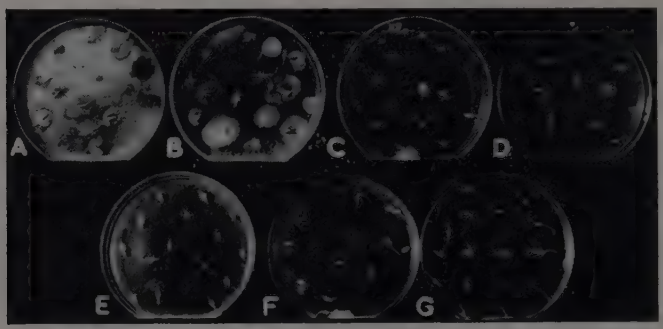

Fig. 3.—Effect of seed treatments on lettuce seed in plating tests. A, Control; B, Cuprocide; C, 10 per cent TMTD; D, 50 per cent TMTD (D); E, 97 per cent TMTD; F, 80 per cent TMTD; and G, 50 per cent TMTD (ND).

Soil Tests

Soil of a medium sandy loam which had given reduced emergence in previous vegetable crops was used both in glasshouse and field trials. Before use in glasshouse trials the soil was air dried and sieved, and its water holding capacity (w.h.c.) as ascertained by the standard method of Keen and Raczkowski (1921) and modified by Garrett (1946), was found to be 56 per cent. Low and medium moisture levels, i.e. 25 and 45 per cent saturation were adjusted before potting, by adding calculated amounts of water to a weighed quantity of soil. Uniformity was obtained by mixing soil and water, first by hand and finally by passing through a 4-mm sieve. The highest level of soil moisture, i.e. 65 per cent saturation, was obtained by adding measured amounts of water to soil already potted.

Circular tins (12.5 cm diameter and 10 cm deep), protected from rust by a thin film of bituminous paint and each holding 1 kg soil were used in glasshouse tests. Before sowing, approximately 100 g of soil for small, or 200 g for large seed, was removed from each tin. The surface of the remaining soil was lightly tamped down, 50 lettuce or 25 pea seeds were sown in concentric circles, and the soil previously removed was replaced and levelled, giving a surface 3 cm below rims of tins. This method gave a depth of sowing of 1.2 cm for lettuce and 3 cm for pea seed.

Each trial was replicated four times and tins were placed on benches in a randomized order. The glasshouse temperature ranged from 15 to 18° c. Tins were covered with glass squares to avoid loss of moisture and these were removed when seedlings grew tall enough to reach them.

Weight of tins was checked on alternate days. No loss of moisture was recorded until removal of glass covers, deficiencies being made up afterwards by sprinkling water over the soil surface.

Seedlings were dug out 15 and 30 days after emergence of lettuces or peas respectively, counted and examined for lesions, separate records being made for healthy and diseased seedlings. The latter included plants showing obvious symptoms of post-emergence damping-off as well as plants showing lesions which would not have affected survival. Height of plants from ground-level and fresh weight of healthy seedlings were recorded in some trials.

Isolations were made from 100 ungerminated seeds and from abnormal or diseased seedlings taken at random from all treatments in glasshouse and field trials.

TABLE IV. MEAN PERCENTAGE EMERGENCE (ACTUAL VALUES) FROM THREE SOIL MOISTURE LEVELS IN GLASSHOUSE TRIALS. (FIGURES UNDERLINED ARE SIGNIFICANTLY DIFFERENT FROM CONTROL AT 5 % LEVEL *)

No.	Treatment	Lettuce		Pea	
		Healthy	Diseased	Healthy	Diseased
1	Control	52.3	21.3	36.8	15.5
2	Cuprocide	63.9	3.2	66.2	3.7
3	Spergon	65.9	2.1	80.9	1.2
4	Panogen	65.9	2.2	66.2	9.7
5	TMTD	71.1	0.3	88.2	2.1
6	FDD	77.5	1.8	71.4	8.5
7	Dow 9B	65.5	1.3	44.0	24.6
8	36L	77.1	1.0	76.9	7.6
9	Phygon	51.6	3.1	76.8	2.5
10	ZDD	57.6	6.5	54.7	4.9
11	Calomel	64.1	0.5	57.1	20.5
12	CO	58.6	5.0	46.9	5.0
13	Agranin ND	46.2	0.0	68.7	10.4
14	Fixtan Dust	59.2	2.3	66.6	11.8
15	TMTD (50% ND)	57.8	1.9	65.1	12.3
16	" (50% D)	37.2	3.0	53.3	12.2
17	Sanagran	59.4	1.7	51.1	14.3
18	Agrosan GN	57.8	2.4	49.4	20.3
19	TMTM	47.5	4.9	47.7	21.5
20	Nomersan	49.2	2.4	46.4	20.0
21	CDD	70.5	5.2	43.4	13.1
22	PCDB	61.5	1.1	21.5	39.3
23	Perenox C	59.2	10.3	29.3	13.1
24	CPD	47.8	17.7	32.7	21.0
25	Fixtan L	60.3	4.8	20.7	34.6
26	Barbac	49.3	3.0	31.0	31.6
27	Agranin D	26.0	2.5	39.5	31.5
28	PEPS	57.5	16.0	16.5	44.3
29	Yellow Cuprocide	49.6	20.2	40.6	9.2

* For figures giving difference required for significance at 5% level see Appendix A and B.

For field trials, seed was treated on the day before sowing and placed into envelopes each containing 50 pea or 300 lettuce seeds. Trials were made in blocks composed of 9-ft rod row treatments randomized within each block and replicated in accordance with recognized field plot procedure (Wishart, 1940). Drills were drawn at a depth of 4 cm for pea and 1.5 cm for lettuce. Soil temperature was recorded daily and moisture expressed in percentages of total water-holding capacity was assessed twice weekly. Date of emergence was noted and final records were taken in the manner already described by lifting all plants after sufficient time had elapsed for maximum emergence to take place.

Results were subjected to analysis of variance. Percentages emergence in sets of data containing values below 20 per cent or above 80 per cent were transformed to corresponding angular values before analysis (Fisher and Yates, 1948). Data containing values of 0.0 per cent were transformed to $\sqrt{(x + \frac{1}{2})}$ for analysis. For clearer interpretation of results, tables in the text contain actual values whilst those in the appendix contain transformed values. Significant differences at 5 per cent level, higher than controls for healthy seedlings and lower than controls for diseased seedlings, are underlined in the tables.

Glasshouse Trials:

Table IV gives the summarized results (mean actual values) of experiments carried out in the glasshouse (16.5°c. $\pm$ 2.5) with 28 materials, in soil maintained at three moisture levels, i.e. 25, 45 and 65 per cent w.h.c. The full data (transformed values) for each soil moisture content are given in the appendix (Tables A and B). Materials were applied at rates rceommended by the manufacturers, viz. for lettuce, 2 per cent of seed weight with exception of Panogen and Fixtan L which were applied at 0.5 per cent; for peas at the rate of 0.25 per cent.

As emergence in soil tests was optimum at medium moisture (45 per cent w.h.c.) sowing in dry soil (25 per cent w.h.c.) gave valuable information on phytocidal effects of some materials, and provided in wet soil (65 per cent w.h.c.) a drastic test of protectant action in conditions adverse to emergence. There is fair agreement in the results obtained with Cuprocide, Spergon, Panogen, TMTD, FDD, Dow 9B and 36L, with the two species of plants used, e.g., substances which enhance emergence with lettuce generally have a similar effect with peas. Other treatments, e.g., Phygon, ZDD, Calomel, CDD and PCDB showed more selective effects, i.e. gave better protection for one species of plants than for the other. Although total emergence of lettuce seedlings was little affected by treatments, many materials improved stand of healthy plants. Cuprocide containing the highest percentage cuprous oxide (94 per cent) was more effective than materials containing less Cu_2O, viz. CO, Perenox C, and Yellow Cuprocide, thus confirming the findings of Anderson, Kadow and Happerstead (1937) that cuprous oxides suitable for seed treatments should not contain less than 95 per cent Cu_2O. A similar tendency was observed with different concentrations of TMTD, e.g., TMTD, TMTD (50 per cent ND), TMTD (50 per cent D) and Nomersan.

The effect of treatments on seedling vigour as measured by average height and average wet weight also gave an indication as to protective action of treatments in soil. Data are not included in the table but a greater significant increase in plant vigour was obtained for pea than

for lettuce. In general, materials effectively increasing percentages of total emergence of peas over controls, viz. Spergon, Panogen, TMTD, FDD, and Phygon also gave increased plant vigour. The method of recording plant growth was, however, not accurate enough to give definite indication as to the value of some materials over others in increasing plant vigour.

Separate records of healthy and diseased seedlings gave a better indication of the effect of treatments than did records of total emergence. Counts of diseased plants, however, included some with only very light lesions. These may have survived and grown into plants similar to those derived from healthy seedlings. Results, however, suggest that treatments, although not giving fungicidal protection against post-emergence damage appear to bring about increased vigour enabling a greater number of seedlings to survive pre- and to resist post-emergence attack. The high frequency of *Pythium, Rhizoctonia* and *Fusarium* (Appendix, Table C) in diseased tissues suggests that these fungi are the main causes of rotting of seed and damping-off of seedlings. Other organisms appear to be secondary invaders, which often tend to obliterate the causal organisms. High incidence of bacterial contamination is often associated with presence of nematodes in large numbers.

Data for the various soil moistures (Appendices A and B) show that high moisture content greatly reduced the efficiency of some materials, e.g. CO, Sanagran, TMTM, CDD, PCDB, CPD, Barbac, Agranin D and PEPS, when applied to peas. A similar effect on lettuce was brought about with TMTD (50 per cent D) and Nomersan. Some treatments, e.g., Dow 9B, TMTM, Barbac, and Agranin D, reduced emergence of lettuce seed in the lowest level of soil moisture. Others applied to pea seed had similar effects, e.g., Perenox C and Yellow Cuprocide.

TABLE V. PERCENTAGE EMERGENCE IN A PRELIMINARY FIELD TRIAL. (FIGURES UNDERLINED ARE SIGNIFICANTLY DIFFERENT FROM CONTROL AT 5% LEVEL).

No.	Treatment	Lettuce		Pea	
		Healthy	Diseased	Healthy	Diseased
1	Control	38.6	14.6	53.8	16.2
2	Cuprocide	55.0	5.4	72.4	7.9
3	Spergon	58.6	3.8	73.2	6.6
4	Panogen	56.4	4.5	73.4	8.8
5	TMTD	52.7	6 2	78.0	6.2
6	FDD	49.7	6.0	74.8	12.2
7	Dow 9B	45.9	2.6	68.8	8.0
8	36L	49.7	7.3	80.0	6.0
9	Phygon	38 6	10.0	76.8	8.4
10	ZDD	43.5	7.0	50.8	13.6
11	Calomel	40.6	6.8	65.4	5.7
12	CO	51.2	5.3	50.8	12.6
Difference required for significance at 5% level		4.5	4.1	14.4	5.4

These effects point to phytocidal damage under dry soil conditions. However, in general, untreated as compared with treated seed gave lower emergence in all moisture levels, results for peas being more obvious.

Field Trials:

Table V gives the results of a field trial carried out with materials selected on the basis of the above glasshouse tests. The average daily temperature was 14.9°c. (± 1.3) and soil moisture 43.7 per cent (± 2.7 per cent) w.h.c.

Emergence of lettuces and peas gave evidence for correlation with results from glasshouse trials. Cuprocide, Spergon, Panogen, TMTD, FDD, Dow 9B and 36L gave satisfactory results with both species of plants. Other materials were more specific in their effect, e.g., Phygon was more effective on peas, whereas ZDD and CO were more effective on lettuces. Records of plant growth were taken and gave some information on vigour brought about by treatments. A more accurate way of

APPENDIX A. PERCENTAGE HEALTHY AND DISEASED LETTUCE SEEDLINGS (TRANSFORMED VALUES) IN SOILS OF DIFFERENT MOISTURE CONTENT

No.	Treatment	Percentage Healthy Seedlings in Soil at w.h.c. *				Percentage Diseased Seedlings in Soil at w.h.c. *			
		25%	45%	65%	Mean	25%	45%	65%	Mean
1	Control	54.9	56.6	27.5	46.3	3.5	4.4	5.7	4.5
2	Cuprocide	53.4	72.3	37.2	54.3	2.1	0.8	1.7	1.5
3	Spergon	65.3	66.0	34.1	55.1	0.7	0.7	2.2	1.2
4	Panogen	55.6	67.6	41.2	54.8	1.9	0.7	1.7	1.4
5	TMTD	62.2	60.3	50.3	57.6	0.7	0.9	0.8	0.8
6	FDD	61.0	61.0	62.9	61.6	0.8	1.1	2.0	1.3
7	Dow 9B	29.7	73.0	63.8	55.5	2.5	1.1	0.7	1.4
8	36L	62.2	67.2	55.6	61.7	0.7	0.7	1.9	1.1
9	Phygon	48.2	59.2	30.0	45.8	0.7	1.0	2.9	1.5
10	[illegible]	61.7	44.8	44.0	50.2	0.9	3.7	2.5	2.4
11	Calomel	45.5	70.6	46.3	54.1	2.1	0.7	0.7	1.2
12	CO	51.4	56.0	43.0	50.0	0.7	2.8	2.1	1.9
13	Agranin ND	41.0	55.8	31.4	42.7	0.7	0.7	0.7	0.7
14	Fixtan D	54 1	64.2	33.6	50.6	2.0	1.6	1.6	1.7
15	TMTD (50% ND)	54.6	60.7	42.1	49.1	0.7	2.8	1.3	1.6
16	TMTD (50%D)	62.7	28.7	21.0	37.5	0.7	2.0	1.2	1.3
17	Sanagran	48.2	61.7	41.9	50.6	2.3	1.8	0.7	1.6
18	Agrosan GN	59.0	52.5	37.6	49.7	2.3	0.7	2.4	1.8
19	TMTN	36.6	68.9	26.3	43.9	0.7	2.0	3.0	1.9
20	Nomersan	54.6	64.0	24.6	44.4	1.0	1.8	1.5	1.4
21	CDD	62.0	61.9	48.2	57.4	0.7	3.0	2.4	2.0
22	PCDB	45.1	70.9	40.7	55.6	0.7	1.9	0.7	1.1
23	Perenox C	56.1	55.6	39.6	50.4	0.7	3.4	4.3	2.8
24	CPD	56.6	36.5	38.3	43.8	2.3	2.8	6.2	3.8
25	Fixtan L	57.3	61.0	34.7	51.0	2.5	2.5	1.6	2.2
26	Barbac	25.8	64.6	43.4	44.6	0.7	2.6	1.2	1.5
27	Agranin D	25.3	36.4	29.6	30.4	0.7	2.4	1.2	1.4
28	PEPS	64.4	45.0	39.9	49.8	0.7	622	2.9	3.3
29	Yellow Cuprocide	47.0	45.1	42.1	44.7	2.8	3.7	4.2	4.3

Difference required for significance at 5% level — Treatment X Moisture level: H=3.9; D=0.16
Means: H-6.3; D=0.5

* Water holding capacity.

assessing vigour would, however, be necessary to give reliable indications of either stimulation of growth by some chemicals or increased vigour of plants due to disease control.

APPENDIX B. PERCENTAGE HEALTHY AND DISEASED PEA SEEDLINGS (TRANSFORMED VALUES) IN SOILS OF DIFFERENT MOISTURE CONTENT

No.	Treatment	Percentage Healthy Seedlings in soil at w.h.c. *				Percentage Diseased Seedlings in soil at w.h.c. *			
		25%	45%	65%	Mean	25%	45%	65%	Mean
1	Control	44.7	47.0	15.3	35.7	22.5	24.7	22.1	23.1
2	Cuprocide	56.6	63.0	44.7	54.8	9.0	14.0	9.3	8.1
3	Spergon	70.6	72.5	51.3	64.8	8.1	5.7	6.0	6.6
4	Panogen	52.0	77.1	39.9	56.3	19.2	13.5	20.9	17.9
5	TMTD	71.9	73.6	65.1	70.2	9.7	5.7	8.9	8.1
6	FDD	53.4	73.5	49.3	58.7	25.8	9.1	11.5	11.5
7	Dow 9B	53.9	40.3	29.9	41.4	22.8	31.2	34.4	29.5
8	36L	68.7	71.4	47.9	62.5	11.9	8.4	23.4	16.3
9	Phygon	64.6	71.2	50.2	62.0	9.1	7.0	10.5	8.9
10	ZDD	58.5	62.1	21.4	47.3	14.7	15.2	5.7	8.9
11	Calomel	50.7	52.6	44.0	49.1	30.6	25.9	23.8	26.8
12	CO	49.1	62.2	13.5	41.6	15.4	14.2	5.7	8.8
13	Agranin ND	59.9	67.8	42.4	56.7	22.6	17.0	15.3	18.3
14	Fixtan D	53.5	65.9	46.0	55.1	27.4	11.7	18.2	19.1
15	TMTD(50%ND)	67.2	68.2	29.5	55.0	9.0	11.1	33.6	17.9
16	" (50% D)	65.1	49.6	26.4	47.0	9.7	22.7	25.9	19.4
17	Sanagran	63.5	56.6	11.2	43.8	19.6	25.0	22.0	22.2
18	Agrosan GN	52.2	53.9	26.8	44.3	24.6	21.3	33.3	26.4
19	TMTM	50.9	63.7	9.0	41.2	30.6	18.5	32.2	27.1
20	Nomersan	60.1	40.9	27.5	42.8	15.5	35.3	26.0	25.6
21	CDD	58.7	47.0	11.3	39.0	16.4	25.4	20.7	20.8
22	PCDB	32.7	34.1	11.2	26.0	37.6	42.5	36.3	29.1
23	Perenox C	13.5	57.6	19.4	30.2	12.2	20.1	28.4	20.2
24	CPD	57.7	28.6	11.1	32.5	19.1	45.8	5.7	23.5
25	Fixtan L	35.3	29.0	13.4	25.9	42.4	35.4	29.8	35.8
26	Barbac	35.0	50.1	6.4	30.5	37.2	24.2	40.0	33.8
27	Agranin D	38.1	56.6	5.7	33.5	37.4	16.7	44.5	32.9
28	PEPS	35.3	22.2	7.6	21.7	48.3	41.3	35.6	41.7
29	Yellow Cuprocide	20.6	63.5	32.5	38.9	15.8	14.7	22.2	11.8
Difference required for significance at 5% level				Treatment X Moisture Level Means		H=9.0; D=15.6; H=5.2; D=9.0.			

* Water holding capacity.

CONCLUSIONS

Twenty-eight materials were examined in various laboratory and soil tests for their suitability as protectants of lettuce and pea seed. As the applicability of laboratory methods to the practical problem was found somewhat uncertain, soil tests were finally used for the estimation of efficacy of various treatments. On the basis of these Cuprocide, Spergon, Panogen, TMTD, FDD, Dow 9B and 36L were found to give satisfactory protection of both lettuce and pea seed under various conditions of soil moisture.

APPENDIX C. ISOLATIONS FROM GLASSHOUSE AND FIELD TRIALS

Percentage Organisms	From Lettuce		From Pea	
	Glasshouse Trials	Field Trials	Glasshouse Trials	Field Trials
Pythium spp.	41.0	36.0	34.0	44.0
Fusarium spp.	60.0	20.0	61.0	42.0
Rhizoctonia spp.	28.0	13.0	22.0	20.0
Phoma spp.	3.0	11.0	2.0	12.0
Stemphylium spp.	5.0	8.0	-	-
Alternaria spp.	6.0	12.0	1.0	3.0
Mucor spp.	10.0	4.0	12.0	6.0
Penicillium spp.	1.0	8.0	4.0	6.0
Cephalosporium spp.	6.0	5.0	3.0	6.0
Trichoderma spp.	3.0	2.0	2.0	3.0
Bacteria	21.0	3.0	35.0	53.0
Other organisms	2.0	7.0	7.0	18.0
Nematodes	5.0	13.0	35.0	52.0

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RANGITOTO SANDY LOAM—A "PROBLEM" SOIL

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Summary

Rangitoto sandy loam is derived from basic volcanic ash and covers most of Motutapu Island in the Hauraki Gulf.

The soil has a high pH (7.0), is well supplied with calcium, potash, magnesium and total nitrogen, but is low in available phosphorus. Pasture establishment has proved difficult and pot experiments indicate that the failure of clover growth is largely due to rapid "fixation" of the phosphate added in fertilizers. Although total nitrogen is high, available nitrogen is low and rye grass does not readily become established without small additions of sulphate of ammonia. Small amounts of copper, zinc, and manganese all give an improvement in yield but their stimulating effect is inclined to be erratic.

Introduction

The island of Motutapu lies in the Waitemata Harbour adjacent to the volcanic cone of Rangitoto, a landmark well known to all who enter or leave New Zealand through the port of Auckland. Rangitoto erupted in recent times—possibly since the arrival of Polynesian culture—and its ash lies thickly on Motutapu Island.

Motutapu Island is formed of sandstone and greywacke, but where the relief is undulating or rolling, the soils are derived from black basaltic ash. This deposit, considered to be a subaerial deposit from Rangitoto,[1] has an average depth of 14 in. on ploughable slopes and forms an intermittent mantle on moderately steep slopes. Many of the hill soils are derived from sandstone and greywacke, and these, in common with soils buried beneath ash, are strongly leached or weakly podzolized, strongly weathered yellow brown earths.[2] Soils derived from the ash are, by contrast, weakly weathered and as yet only slightly leached. They are classified as azonal soils—recent soils developing in volcanic ash. The main soil developing in the ash on Motutapu Island is known as Rangitoto sandy loam, and is shown on the Soil Map of New Zealand (North Island)[3] as 5e.

The vegetation on Motutapu Island when Europeans arrived was mainly scrubland (dominated by *Leptospermum scoparium*) and mixed coastal forest (predominantly broadleaf trees, *Griselinia, Corynocarpus,* etc.); but the degree of leaching in soils derived from sandstone and greywacke rather suggest that "mor" forming trees such as *Agathis australis, Podocarpus* spp., *Dacrydium cupressinum,* etc., formerly covered much of the island.

A typical profile of Rangitoto sandy loam shows:—

6 in. black sandy loam or loamy fine sand;
10 in. blackish medium sand (free); } (derived from ash)

6 in. greyish-brown sand (slightly compact), grading into pale greyish-white silt loam;

4 in. brown to orange brown silty clay loam;
on brownish-yellow clay. } (derived from greywacke)

The base status of four horizons of the above profile was determined by Mr. Browning of the Soil Bureau. The results are given in Table I.

Rangitoto sandy loam is a deep well-drained soil with no markedly unusual physical characteristics. The rainfall in the area is about 50 in. per annum, well distributed throughout the year, so that water holding capacity is unlikely to be a factor limiting plant growth.

The topsoil is strongly melanized but a C/N ratio of 14 (Table I) indicates that the soil carbon and nitrogen are very well balanced. The humus is mellow and there is no indication of abnormal microbiological metabolism. Mr. J. D. Stout of the Soil Bureau examined the protozoa in this soil and reported that the fauna was not markedly different from that encountered in fertile soils elsewhere in North Auckland.

The base status analysis clearly differentiates the ash-derived soil from the underlying soil formed from sedimentary rocks, and further shows that the latter soil has been enriched with lime and magnesia leached from the horizons above. In the topsoil horizons, potash, lime, and magnesia are all fairly high in comparison with fertile New Zealand soils; pH is very high, and the only low figure is that for available phosphate. The virgin soil is characterised as having high lime, low phosphate, and moderate potash.

TABLE I. PARTIAL CHEMICAL ANALYSIS OF RANGITOTO SANDY LOAM

Depth (in.)	pH	P_2O_5 * (%)	C (%)	N (%)	C/N	B.E.C. (m.e.%)	T.E.B. (m.e.%)	B.S. (%)	CaO (m.e.%)	MgO (m.e.%)	K_2O * (m.e.%)
0-5	6.9	0.008	8.2	0.59	14	44.5	36.8	83	27.4	8.1	0.026
6-12	7.3	0.007	-	-	-	42.6	27.3	64	20.0	5.8	0.023
16-21	7.5	0.023	-	-	-	12.7	11.5	91	8.6	2.0	0.015
22-28	7.6	0.004	-	-	-	20.4	17.5	86	11.0	5.9	0.012

* "Available" fraction as estimated by extraction with 1% citric acid.

NOTE:- B.E.C. = Base exchange capacity
T.E.B. = Total exchange bases
B.S. = Base saturation

Much of the existing pasture on the island consists of poor *Danthonia* spp. with a high proportion of ratstail (*Sporobolus capensis*) and various "flat weeds." It was reported[4] that ploughing followed by resowing with high-fertility pasture mixtures had met with but limited success. This could not readily be explained by consideration of the partial soil analyses shown in Table I, for the simple application of phosphatic fertilizer should suffice to bring Ca, Mg, K, and P levels close to the calculated optimum for plant growth. There was the obvious possibility that this soil possesses to a high degree the power to fix added phosphates but this is not usually encountered in soils with a high exchangeable calcium status. Accordingly, it was decided to investigate the fertility of this soil in a series of pot trials.

TABLE II. TREATMENTS APPLIED IN PILOT EXPERIMENT WITH RANGITOTO SANDY LOAM

Treatment No.	Treatment designation	Relative ratio of major nutrient elements.	Treatments
1	Control	High Ca : low P : mod. K	None
2	Low P	High Ca : mod P : mod. K	Na_2HPO_4 at rate equivalent to $2\frac{1}{2}$ cwt per acre.
3	High P *	High Ca : High P : Mod. K	" " 5 "
4	Low K	High Ca : low P : high K	K_2SO_4 " " $2\frac{1}{2}$ "
5	High K	High Ca : low P : Very high K	" " 5 "
6	Low P K	High Ca : mod P : high K	As for treatments Nos. 2 and 4.
7	High P K *	High Ca : high P : high K	" " 3 and 4.
8	High Mg	" " "	As for treatments No. 7 + $MgSO_4$ at rate equivalent to 150 lb per acre.
9	Mo	" " "	As for treatments No. 7 + $MgSO_4$ at rate equivalent to 75 lb per acre and NH_4MoO_4 at rate equivalent to 2 lb per acre.
10	B	" " "	As No. 9 but $Na_2B_4O_7$ at rate equivalent to 40 lb per acre
11	Cu	" " "	As No. 9 but $CuSO_4$ at rate equivalent to 20 lb per acre.
12	Zn	" " "	As No. 9 but $ZnSO_4$ " 20 lb "
13	Fe	" " "	As No. 9 but $FeSO_4$ " 25 lb "
14	Mn	" " "	As No. 9 but $MnSO_4$ " 25 lb "
15	Leached **	Mod.Ca : high P : mod. K	As No. 8 but soil previously leached with weak acid.
16	Leached ** + trace element	" " "	As No.15 but complete trace element supplied.
17	Sterilized	High Ca : high P : high K	As No. 8 but soil previously sterilized.
18	Re-inoculated	" " "	As No.17 but soil re-inoculated.
19	S	High Ca : mod. P : high K	As No. 6 but flowers of sulphur added at rate equivalent to 500 lb per acre.
20	Nitrogen	" " "	As No. 6 but $(NH_4)_2SO_4$ added at rate equivalent to $1\frac{1}{4}$ cwt per acre.

* Phosphate added in an acid-washed silica-sand layer to minimize fixation.
** Soil leached to remove possible toxic factors with distilled water acidified with hydrochloric acid: treatment continued until soil reached pH 5.4.
(All components used were grade A.R. except flowers of sulphur)

Experimental Methods

A pilot experiment was carried out in waxed 4-inch earthenware pots, using mustard as the indicator plant. The treatments listed in Table II were carried out in triplicate.

The pilot experiment was conducted in a glass house during July and August, 1948. Following mustard, a succession crop of ryegrass and white clover was sown in the pots (without further treatment) and this was harvested in December, 1948.

A further trial, with this soil type, was set outside in August, 1948, in large earthenware pots, which were sown down to ryegrass and white clover pasture. The treatments (in triplicate) in this experiment are listed in Table V.

Results

Pilot trial with Mustard

Seed was sown on 10 July. Extra nitrogen (No. 20) and the two treatments with sterilized soil (Nos. 17 and 18) showed an early stimulus which persisted until harvest on 6 September. Growth was estimated on average height of stems and average dry weight per plant. Sterilization (No. 17) of the soil markedly improved growth, especially when re-inoculated (No. 18) with a small quantity of fertile garden soil. Sulphate of ammonia (No. 20) showed a fairly consistent response, and with zinc (No. 12) and manganese (No. 14) plants responded very strongly, bringing up the average result for the whole treatment. Potash exerted a marked depressing effect on growth, especially where accompanied by only a light phosphate dressing (Nos. 2, 4 and 5). Percolating dilute hydrochloric acid through the soil prior to the experiment (Nos. 15 and 16) had a marked detrimental effect. The results are summarized in Table III.

A succession crop of ryegrass and white clover was sown in these pots on 14 September. By 27 September growth of both ryegrass and clover had markedly improved with treatments Nos. 3 and 7. The depressing effect of leaching (Nos. 15 and 16) was no longer evident, nor was the stimulation of nitrogen (No. 20) as marked as formerly. Potash without additional phosphate again depressed growth, while the sterilized soil (Nos. 17 and 18) stimulated ryegrass very markedly. Clover did not make especially good growth in these treatments. Zinc had a favourable effect on the growth of ryegrass. At harvest on 3 December the combined dry weight of ryegrass and clover was taken as the best measure of growth. This showed that sterilization had effected the greatest change in the fertility of the soil (Nos. 17 and 18), and that zinc had again given a marked (but not always consistent) stimulus. Potash added by itself had a serious depressing effect on growth of both species, but phosphate added in a sand layer gave a marked improvement in growth, especially in the case of clovers. The results of this experiment are shown in Table IV.

In some treatments there was a marked difference in relative growth between ryegrass and clover. Ryegrass was growing well in treatments Nos. 17 and 18 but the clovers were amongst the poorest in the series. On the other hand, the best treatments for clover (Nos. 7 and 3) produced only moderately good growth in ryegress. After harvesting, clover roots were examined for nodulation. Numerous large nodules characterized clover roots in treatment No. 3 while numerous medium size nodules were present on roots in treatments Nos. 7, 9, 10, 15 and 16. Nodulation was exceptionally poor in treatments Nos. 1, 4, 5, 17, and 18.

TABLE III. PILOT EXPERIMENT WITH RANGITOTO SANDY LOOM: MUSTARD CROP

Treatment No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average height in cm	6.6	6.4	7.6	5.9	5.8	7.5	7.4	7.2	8.5	6.4	7.7	8.6	7.4	8.2	4.5	4.4	13.4	13.8	4.4	8.1
Average dry weight in g	0.05	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.09	0.05	0.07	0.01	0.01	0.12	0.19	0.04	0.09
Rating position (1 = best, 20 = worst)		16		17	18							3		5	19	20	2	1		4
pH of composite *	7.7	7.5	7.6	7.7	7.8	7.8	7.5	7.7	7.6	7.6	7.5	7.7	7.4	7.4	7.5	7.5	7.3	7.4	7.2	7.0
N in composite ** soil sample	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.5	0.5	0.5	0.5

* pH measurements made on samples of soil withdrawn from top two inches with a cork borer.

** Total nitrogen determinations made by Mr. H.W. Johnston, Soil Bureau.

TABLE IV. PILOT EXPERIMENT WITH RANGITOTO SANDY LOOM: RYE AND CLOVER CROP

Treatment No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average width of clover leaves 27/10/48	4.8	4.7	5.9	4.7	4.5	5.3	6.2	5.0	4.9	5.1	5.1	5.5	5.4	5.3	5.6	5.7	5.5	5.2	5.0	5.5
Average height of rye grass plants 27/10/48	6.8	8.5	9.6	6.1	6.1	8.7	10.4	8.0	7.9	8.4	9.1	10.1	8.6	8.3	7.8	8.4	11.7	11.7	7.1	7.8
Average dry wt. of each plant 3/12/48	0.15	0.42	0.51	0.12	0.08	0.29	0.57	0.31	0.31	0.32	0.31	0.69	0.41	0.41	0.38	0.40	0.62	0.70	0.25	0.31
Rating position (1 = best) (20 = worst)	18			19	20							2					3	1		

Main Trial with Ryegrass and White Clover

This was carried out in 9-inch pots which were kept outside throughout the experiment. Certified ryegrass (G.S. Ba 6802) and white clover (G.S. 2590), obtained from Grasslands Division, were sown in a ratio of 1 : 1 at a rate of 52 seeds per pot. After thinning there were 13 plants of each species in each pot.

TABLE V. TREATMENTS APPLIED IN FINAL TRIAL WITH RANGITOTO SANDY LOAM.

Treatment No.	Treatment	Rate
21	Blood and bone	Equivalent to 2½ cwt per acre
22	Superphosphate	„ „ 5 „ „ „
23	Sulphate of ammonia	„ „ 1½ „ „ „
24	Superphosphate and sulphate of ammonia and manganese and copper.	As for treatment Nos. 22 and 23 + $CaSO_4$ at rate equivalent to 10 lb acre $MnSO_4$ „ „ „ „ 12½ lb acre

Note.—All materials used were commercial grade.
The final trial was harvested in March, 1949.

This experiment was commenced on 1 September 1948. Emergence counts showed no significant differences among the treatments. By 10 October the two treatments with phosphate showed a marked superiority and treatments 1 and 2 showed distinct signs of phosphate deficiency (Fig. 1). The blood-and-bone treated soil was growing particularly poor clover, and only fairly good ryegrass plants. Accordingly two replicates each of treatments 1 and 2 were topdressed with superphosphate at a rate equivalent to 5 cwt per acre. There was an immediate improvement in clover growth and subsequently the ryegrass commenced to make rapid growth. Two cuts were made, the first on 4 December, 1948, and a final harvest on 31 March, 1949; the dry-weights recorded are shown in Table VI.

TABLE VI. MAIN EXPERIMENT WITH RANGITOTO SANDY LOAM : RYE GRASS AND CLOVER CROP.

Treatment	1st Harvest : 4/12/48		2nd Harvest : 31/3/49	
	Average dry weight (g)		Average dry weight (g)	
	Clover	Rye	Clover	Rye
21. Blood and bone	0.20	1.44	0.88	5.71
21a Blood and bone, topdressed with superphosphate	0.33	2.03	2.30	4.97
22. Superphosphate	0.88	4.34	7.76	6.13
23. Sulphate of ammonia	0.15	1.21	Nil	5.84
23a Sulphate of ammonia, topdressed with superphosphate	0.28	2.23	1.92	5.15
24 Superphosphate + S/A + Zn + Cu.	1.06	5.61	8.31	6.48

FIG. 1.—Rangitoto sandy loam sown to ryegrass and white clover. Photo taken two months after seed sown.

Pot No. 1.—Sulphate of ammonia at 1¼ cwt to the acre.
Pot No. 2.—Blood and bone at 2½ cwt to the acre.
Pot No. 3.—Superphosphate at 5 cwt to the acre.
Pot No. 4.—Superphosphate (5 cwt), sulphate of ammonia (1¼ cwt), zinc sulphate (12½ lb) and copper sulphate (10 lb). (All quantities calculated on an acre basis.)

DISCUSSION

The pilot experiment indicated fairly clearly that phosphate and nitrogen were the two main requirements for normal plant growth on Rangitoto sandy loam. The direct application of nitrogen as sulphate of ammonia was effective, but only where the phosphate status of the soil had been previously improved. Phosphate fixation has been demonstrated in the case of soil types similarly derived from basalt[5] in the nearby North Auckland peninsula, although these soils are generally more strongly weathered and more leached. However, phosphate fixation is rarely reported from soils with high exchangeable calcium, and further work is being done in connection with phosphate fixation by Rangitoto sandy loam.

It was not possible to arrange for a survey of the micro-organisms in the variously treated soil in the pots, but it was evident that microbiological factors were in some way closely implicated in the apparent infertility of Rangitoto sandy loam. It is noteworthy that the virgin soil has a high total nitrogen content, yet in the pilot experiment sterilization had a marked and persistent influence on the fertility of the soil; moreover, the effects were not greatly modified in the treatments where the sterilized Rangitoto sandy loam was re-infected by inoculation with a very small quantity of fertile garden soil. Stout[6] has confirmed that steam sterilization affects the protozoan fauna. His examination of uncultivated samples of Rangitoto sandy loam failed to disclose any unusual species amongst the protozoan population. For the earlier crop (mustard) the beneficial results of sterilization may largely be accounted for by indirect increase in available soil nitrogen, and the failure of nodules in the following clover crop may be ascribed to the direct action of high temperatures on nodule-forming bacteria. The marked stimulatory (but irregular) effects of zinc, and to a lesser extent of copper

and manganese, in some pots suggest that there was a microbiological variation among pots. It is possible that growth was accelerated by additional fixation of nitrogen resulting from increased microbiological activity due to the addition of zinc, copper, etc. Boron and molybdenum had the expected stimulatory effect on clover nodulation, but growth was not otherwise greatly improved.

Leaching of the soil with very dilute hydrochloric acid, designed to reduce any possible toxic inorganic factor, had a serious detrimental effect on the growth of mustard, but no appreciable effect on the ryegrass and clover crop that followed. This suggests that the leaching introduced some temporary toxic factor, such as Cl-ions, and had not removed any inherent toxic factor nor seriously lowered the base status.

The depressing effect on growth of additional potash (without simultaneous addition of extra phosphate) was extremely marked, suggesting that the Rangitoto sandy loam had adequate potash for normal growth.

To establish and maintain high producing pastures, a good growth of clover is essential. Establishment of clover on Rangitoto sandy loam appears to depend largely upon provision of extra phosphate, preferably in some form which is not readily "locked up" by interaction with the soil. The main experiment demonstrated the beneficial results of heavy applications of superphosphate, and showed that the yield could be further raised if sulphate of ammonia (with traces of zinc and copper) were incorporated with the superphosphate treatment. The main effect of sulphate of ammonia appeared to be the stimulation of the early stage of growth in ryegrass seedlings. Blood and bone, or sulphate of ammonia, used without a phosphate fertiliser, brought on conspicuous symptoms of phosphate deficiency, from which there was subsequent recovery with the blood and bone treatment, but none with sulphate of ammonia. Topdressing with superphosphate quickly remedied the deficiency. From these pot experiments it would appear that the problem of pasture establishment on Rangitoto sandy loam centres around provision of adequate phosphate for steady clover growth and provision of adequate nitrogen to maintain the growth of young ryegrass seedlings until the mechanism of nitrogen fixation by clover is well established. Potash manures should probably not be used for several years from the start of bringing in new ground. Occasional light dressing (5-10 lb per acre) of zinc, copper, and manganese sulphate would probably also be worthy of field trials.

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THE EFFECTS OF CHEMICALS AND ANTIBIOTIC SUBSTANCES ON CROWN-GALL (*Agrobacterium tumefaciens* (Smith and Townsend) Conn). Part III

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Summary

To control crown-gall, caused by the organism *Agrobacterium tumefaciens*, chemical and antibiotic solutions have been applied to galls on marigold plants. One material was tested on peach seedling galls. Three methods of application, viz. injection, smearing, and brushing, were used.

Crude penicillin (5 and 15 Oxford units (O.U.) per ml) and commercial penicillin (5 Oxford units per ml) neither killed galls nor retarded their further development.

A 25 per cent solution of elgetol in methyl alcohol effectively killed galls on peach seedlings without damaging plant health, but severely damaged marigold plants.

A 2 per cent elgetol solution, iodine, and clove-oil solutions, when smeared or brushed on, caused the rapid death of marigold galls without damaging plants, but when injected killed plants.

Acidulated mercuric chloride 0.1 and 0.4 per cent had no effect on growth of galls except for one treatment (0.4 per cent, brushed) which significantly retarded gall growth.

Tests *in vitro* showed that growth of *A. tumefaciens* was not inhibited by commercial penicillin. Complete inhibition of growth was however brought about by elgetol, iodine, clove oil, and mercuric chloride.

INTRODUCTION

IN continuation of the search for a reliable method of killing galls caused by *Agrobacterium tumefaciens* (Dye *et al.*, 1950; Dye and Hutchinson, 1950), further experiments have been carried out and results are presented in this paper. Treatments with iodine and with clove oil, which in previous tests (Dye and Hutchinson, 1950) killed plants, have been repeated at lower concentrations and further tests with penicillin have also been made. As Brown and Boyle (1945) obtained good results by applying crude penicillin containing 6 Oxford units per ml in cotton wool wrapped around galls, a similar method of application was included in these tests.

Additional materials tested were acidulated mercuric chloride and elgetol (sodium dinitro-orthocresol). Elgetol was tested because Ark (1941) obtained 100 per cent destruction of almond tree galls by painting them with a solution of 20 vol. elgetol in 80 vol. methyl alcohol.

The effects of the materials on growth of *A. tumefaciens* was also tested *in vitro*.

EXPERIMENTAL METHODS

Materials used in treating Galls:

The following materials were used for treatment of galls.

A. Elgetol as a 2 per cent and a 25 per cent solution in methyl alcohol.

B. Iodine solution consisting of 1 g. of iodine in 25 ml methyl alcohol, 2.5 ml glacial acetic acid, and 12.5 ml glycerine.

C. Clove-oil solution consisting of 3 ml clove oil in 30 ml methyl alcohol and 3 ml glacial acetic acid.

D. Acidulated mercuric chloride prepared from a stock solution containing 40 g mercuric chloride in 100 ml concentrated hydrochloric acid and diluted with water to make concentrations of 0.1 and 0.4 per cent mercuric chloride.

E. Penicillin supplied and assayed by Dr T. R. Vernon, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Auckland, as follows:—

1. A culture fluid of penicillin containing 5 Oxford units per ml.
2. A culture fluid of penicillin containing 15 Oxford units per ml.
3. Commercial penicillin containing 5 Oxford units per ml.

F. Water (control).

Cultural Study:

To determine the effects of the various materials on *A. tumefaciens in vitro,* two-ml portions of solution were each mixed with 12 ml beef-peptone-agar in sterile petri dishes. Crown-gall bacteria were liberally wiped over the agar surface and the petri dishes were incubated for four days at 27°C. *A. tumefaciens* grew vigorously on media containing commercial penicillin but growth was completely inhibited by all concentrations of elgetol, iodine, clove oil, and acidulated mercuric chloride.

Treatment of Galls:

French marigolds (*Tagetes patula* L.) and peach seedlings (*Prunus* persica Sieb. and Zucc.) were grown in earthenware pots containing sterilized soil in a glasshouse with the air temperature between 60° and 80°F. When the marigolds were 3 to 4 in. high and the peach seedlings approximately 12 in. high, plants were inoculated with a 72-hour beef-peptone-broth culture of a virulent strain of *A. tumefaciens.* The method of inoculation was by injection into stems with a hypodermic needle (Dye *et al.,* 1950). Each material was used for treatment of galls on 6 marigold plants 41 days after inoculation. Peach galls were treated only with 25 per cent elgetol in methyl alcohol, 57 days after inoculation.

Three methods of application were used:—

1. By injecting solution into galls with a hypodermic syringe;
2. By smearing each gall with a 1:1 paste of crude lanolin and solution*;
3. By brushing the solution over the surface of each gall.

For application of crude penicillin the following additional method similar to that of Brown and Boyle (1945) was used. Galls were painted with the penicillin solution, wrapped in cotton wool moistened with penicillin, and punctured 5 times through the cotton wool with a coarse blunt needle. More penicillin was then added to the cotton wool. Overnight the stock penicillin solution was kept at 4.5°C. and the above

* In the case of clove oil solution only 9 ml could be mixed in 10 ml of lanolin.

TABLE I. EFFECTS OF TREATMENTS APPLIED TO GROWING BACTERIAL GALLS ON MARIGOLD AND PEACH HOSTS

Treatment		Effect of Treatment on Plants	No. of Galls Treated	No. of Galls Killed	Increase in gall diameter	
Material	Method of Application				Av. for each treatment	Av. for all treatments with each material
					(cm)	(cm)
MARIGOLD						
Penicillin Crude 5 o.u.	Injected	No effect	12	0	0.39	0.37
	Smeared	"	12	0	0.36	
	Brushed	"	12	0	0.36	
	Cotton wool	"	12	0	0.21	
Penicillin Crude 15 o.u.	Injected	"	12	0	0.40	0.34
	Smeared	"	12	0	0.31	
	Brushed	"	12	0	0.32	
	Cotton wool	"	12	0	0.24	
Penicillin Commercial 5 o.u.	Injected	"	12	0	0.52	0.33
	Smeared	"	11	0	0.26	
	Brushed	"	8	0	0.22	
Elgetol 2 %	Injected	3 plants killed	12	12	-	-0.21
	Smeared	No effect	12	12	-0.22	
	Brushed	"	12	12	-0.21	
Elgetol 25 %	Injected	All plants killed	12	12	-	-0.23
	Smeared	No effect	12	12	-0.23	
	Brushed	5 plants killed	12	12	-	
Iodine solution	Injected	5 plants killed	12	12	-	-0.04
	Smeared	No effect	12	12	-0.18	
	Brushed	"	12	5	0.09	
Clove oil solution	Injected	4 dead, 2 damaged	12	12	-	-0.31
	Smeared	No effect	12	12	-0.30	
	Brushed	"	12	8	-0.33	
Acidulated Mercuric Chloride 0.1 %	Injected	"	12	0	0.29	0.41
	Smeared	"	12	0	0.58	
	Brushed	"	12	0	0.36	
Acidulated Mercuric Chloride 0.4 %	Injected	"	12	0	0.21	0.20
	Smeared	"	12	0	0.44	
	Brushed	"	12	0	-0.04	
Water (control)	Injected	"	12	0	0.43	0.52
	Smeared	"	12	0	0.40	
	Brushed	"	12	0	0.72	
	Cotton wool	"	12	0	0.40	
PEACH						
Elgetol 25 %	Injected	"	11	7	0.06	-0.04
	Smeared	"	12	12	-0.13	
	Brushed	"	12	8	-0.04	
Water (control)	Injected	"	11	0	1.20	1.12
	Smeared	"	10	0	1.21	
	Brushed	"	11	0	0.96	

* 42 days after treatment.

Differences necessary for significance		At 5% level	At 1% level
1. Marigold.	a. Between single treatments	0.24	0.32
	b. " groups of two	0.34	0.45
	c. " groups of three	0.42	0.56
	d. " groups of four	0.49	0.64
	e. " groups of six	0.60	0.79
2. Peach.	a. Between single treatments	0.44	0.59
	" groups of three	0.76	1.01

treatment was repeated 24 hours after the first application. After 14 days in position the cotton wool was removed to permit measuring of galls.

Horizontal diameter measurements of all galls were made with sliding vernier calipers at 7-day intervals for 56 days after treatment. Additional measurements of peach galls were continued at 14-day intervals until 97 days after treatment.

RESULTS

Results are given in Table I and statistical analyses of some results are shown in Table II. A graph showing the effects on growth of marigold galls of treatment materials smeared on the galls in lanolin paste is shown in Fig. 1.

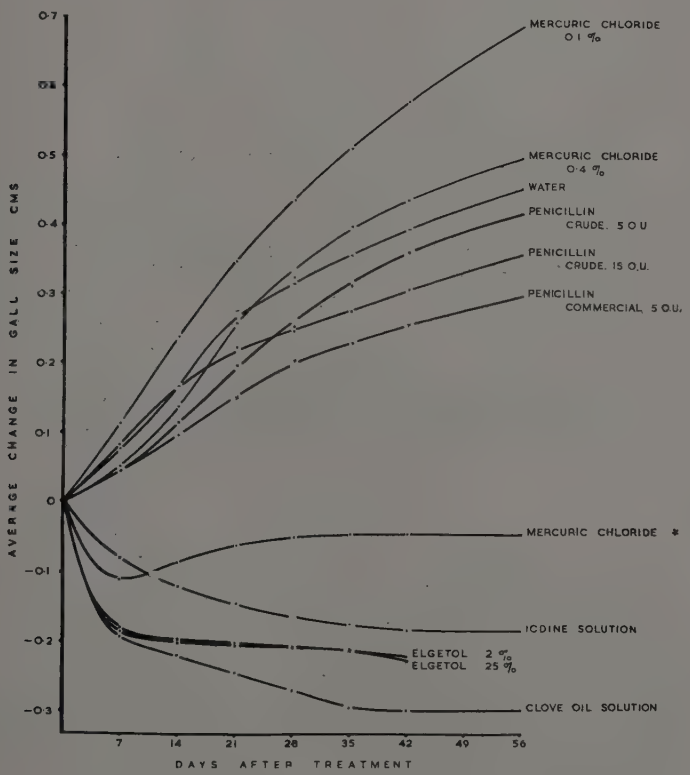

FIG. 1.—A comparison of the effects on marigold galls, of treatment materials smeared on in lanolin paste.

* Acidulated mercuric chloride 0.4 per cent solution brushed on galls.

N.B.—Measurements of elgetol treated galls were discontinued after 42 days since at this time galls dropped from plants.

TABLE II. STATISTICAL ANALYSIS OF RESULTS IN TABLE I

Treatments Compared	Difference in Gall Size	Difference necessary for significance at		Result
		5% level	1% level	
A. Marigolds				
Penicillin 5 O.U. Crude v Control	-0.15	0.42	0.56	
Penicillin 15 O.U. Crude v Control	-0.18	0.42	0.56	
Penicillin 5 O.U. Commercial v Control	-0.19	0.42	0.56	
Elgetol 2% v Control	-0.77	0.34	0.45	Highly significant
Iodine Solution v Control	-0.60	0.34	0.45	"
Clove oil Solution v Control	-0.87	0.34	0.45	"
Mercuric Chloride 0.1% v Control	-0.11	0.42	0.56	
Mercuric Chloride 0.4% v Control	-0.32	0.42	0.56	
Penicillin in cotton wool v Control in cotton wool	-0.18	0.24	0.32	
Mercuric Chloride 0.4% Brushed v Control Brushed	-0.76	0.24	0.32	Highly significant
Methods * Injected v Smeared	-0.02	0.60	0.79	
Injected v Brushed	0.05	0.60	0.79	
Smeared v Brushed	0.07	0.60	0.79	
B. Peach Seedlings				
Elgetol 25% v Control	-1.16	0.76	1.01	Highly significant

* Elgetol, iodine, and cloveroil not included in these comparisons because hosts were severely damaged by injection method. Smeared compared with brushed including all treatments in experiment also gave a non-significant result.

Discussion

In this and previous experiments (Dye *et al.*, 1950), penicillin, both crude and commercial, used at three concentrations, and by four methods of application, has not prevented gall formation nor destroyed existing galls. Elgetol, iodine, and clove oil solutions at the concentrations tested on marigolds, killed galls without affecting plant growth, but when injected caused the rapid death of plants. Elgetol at 25 per cent concentration effectively killed galls on peach seedlings without affecting plant health. Although in general 0.1 and 0.4 per cent acidulated mercuric chloride had no effect on galls, one treatment, 0.4 per cent brushed on, significantly retarded growth.

Over the whole experiment, the three methods of application, viz. injection, smearing, and brushing, gave similar results, but among individual treatments, differences were noted. For instance, elgetol, iodine, and clove oil solutions were most effective when brushed or smeared, whereas acidulated mercuric chloride was least effective when smeared.

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CLIMATE AND FACIAL ECZEMA IN NEW ZEALAND: II

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INTRODUCTION

The purpose of the present paper is to extend the tables given in a previous publication[1] to cover the ten-year period 1939-40 to 1948-49, and to bring up to date the tables of normal monthly mean air and earth temperatures given in that publication. These data are derived from 21 stations scattered throughout the North Island. They give a general picture of the temperatures experienced over the whole island from one season to another.

OCCURRENCE OF FACIAL ECZEMA IN NEW ZEALAND, 1939-1948

Concerning the occurrence of facial eczema during the period 1939-40 to 1948-49, the Director, Animal Research Division, Department of Agriculture, has kindly supplied the observations given in Table I.

TABLE I. OCCURRENCE OF FACIAL ECZEMA IN NEW ZEALAND

1939-40	The trouble nowhere serious.
1940-41	The outbreaks not of a serious nature.
1941-42	The percentage of sheep affected not high.
1942-43	Only a small percentage of animals affected.
1943-44	Very little of the disease reported.
1944-45	The disease practically absent.
1945-46	A few isolated cases.
1946-47	No recognizable outbreaks.
1947-48	Severe widespread outbreaks reported from North Auckland and Waikato. Although severe, the disease widely distributed and no serious concentration of the trouble at any one place.
1948-49	Widespread outbreaks reported in the Auckland and Waikato districts together with odd outbreaks in Poverty Bay, Manawatu and Hawkes Bay.

It may be stated that no widespread outbreak of facial eczema comparable in intensity with those of 1934-35 and 1937-38 has been experienced during the past ten seasons. The difficulty of assigning a numerical index for the intensity of the disease experienced throughout the North Island, renders it impossible to draw other than broad conclusions.

TABLE II. NORMAL AIR TEMPERATURES IN NORTH ISLAND

MEAN AIR TEMPERATURE = ½ (MAXIMUM + MINIMUM)

Station	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Te Paki	60.0	63.2	64.8	65.3	64.0	62.3
Auckland	60.2	63.8	66.4	66.8	64.9	61.2
Maioro	57.7	61.0	63.4	63.9	62.4	59.0
Waihi	58.9	62.1	64.5	64.4	61.8	57.4
Te Aroha	60.6	63.9	67.0	66.2	63.6	58.8
Tauranga	58.8	62.0	64.6	64.9	62.5	58.4
Ruakura	58.0	61.4	63.8	63.9	61.8	57.3
Rotorua	57.8	61.4	64.2	63.6	61.2	56.3
Whakarewarewa	57.4	61.1	63.5	63.1	59.8	56.0
Gisborne	59.7	63.2	65.8	65.1	62.1	58.8
Karioi	51.2	54.4	56.7	56.4	54.1	50.2
Napier	59.8	63.1	65.5	65.4	62.3	58.6
Hastings	59.2	63.1	65.4	65.0	61.6	57.5
Taihape	52.5	56.3	59.2	58.9	56.6	52.5
Wanganui	57.7	61.1	63.3	63.4	61.1	57.8
Tangimoana	57.3	60.7	62.9	63.0	60.7	57.2
Palmerston Nth.	57.0	60.4	62.6	62.3	60.3	56.8
Pahiatua	56.4	60.0	62.0	62.1	59.5	55.6
Masterton	56.6	60.7	63.2	62.6	59.7	55.3
Wallaceville	55.5	59.2	61.4	61.0	58.3	54.2
Kelburn	55.6	59.0	61.2	61.2	59.2	55.7

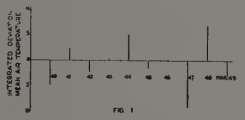
TABLE III. NORMAL EARTH TEMPERATURES IN NORTH ISLAND

EARTH TEMPERATURES °F.

Station	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Depth	
Te Paki	64.9	68.6	71.1	71.4	69.2	64.6	1 ft.	1932-1945.
Auckland	63.4	67.6	70.2	70.1	68.2	63.9	1 ft.	
	61.5	64.8	67.3	69.1	68.5	66.1	3 ft.	
Maioro	63.8	67.8	70.4	70.2	68.8	64.0	1 ft.	1939-1945
	62.2	65.9	68.6	69.4	68.2	66.1	3 ft.	
Waihi	59.5	62.5	65.1	65.4	65.1	62.6	2 ft.	
Te Aroha	66.5	69.9	72.7	72.6	69.6	65.3	1 ft.	1941-1945
Ruakura	60.9	64.0	66.1	65.3	63.2	58.4	4 in.	
	61.8	65.1	67.7	67.1	65.3	60.9	8 in.	
	59.3	62.3	64.9	65.7	65.0	62.5	3 ft.	
Gisborne	65.2	69.1	70.8	69.6	64.2	58.1	4 in.	Dec.1942-Nov.1947
	62.8	67.8	70.2	69.2	65.9	61.0	1 ft.	
	59.5	63.5	66.2	66.9	65.7	62.8	3 ft.	
Napier	63.3	67.9	70.7	70.5	67.8	63.0	1 ft.	
	61.5	65.2	68.8	69.8	68.8	65.9	3 ft.	
Hastings	62.2	66.6	67.2	68.2	61.5	55.3	4 in.	Oct.1942-Oct.1947
	63.0	68.7	71.1	69.9	66.1	59.9	1 ft.	
Taihape	54.8	58.2	60.8	61.5	60.3	57.0	2 ft.	
Palmerston N.	59.0	63.5	65.6	64.0	60.9	55.8	4 in.	
	59.0	63.3	65.4	64.4	61.5	57.0	8 in.	
	59.2	63.9	65.4	64.8	62.2	57.9	1 ft.	
	57.2	61.0	63.2	63.6	62.6	59.8	3 ft.	
Wanganui	61.7	66.1	69.2	67.8	64.9	59.6	1 ft.	1937-1945.
	59.5	64.1	67.0	66.8	65.6	62.2	3 ft.	1937-1945.
Masterton	58.3	62.8	65.4	64.9	61.9	57.0	1 ft.	
Wallaceville	59.3	63.5	65.8	64.3	61.0	56.1	4 in.)	
	59.3	63.9	66.1	65.2	62.4	57.6	8 in.)	1939-1945.
	59.6	63.8	66.4	65.5	62.9	58.3	1 ft.)	
	58.4	61.8	64.6	64.7	63.2	59.7	3 ft.)	
Kelburn	56.9	61.0	63.6	62.6	58.8	53.9	4 in.	Oct.1943-Oct.1947.
	57.0	60.7	63.8	64.0	60.7	55.8	8 in.	Mar.1944-Oct.1947.
	59.6	63.2	65.6	65.2	63.0	58.5	1 ft.	
	57.2	60.8	63.2	63.9	62.9	60.1	3 ft.	

TEMPERATURE DATA

In Tables II and III are given the normal air and earth temperatures derived from observations taken over ten or more consecutive years. Tables IV and V give the integrated deviations from these normals, of air and earth temperatures, respectively, between November and April inclusive, for the stations concerned.



In Fig. 1 the average integrated deviation of air temperatures, taken over all these stations, is plotted against the season, while Fig. 2 gives the average deviation of the mean monthly air temperature, taken over these stations, again plotted against season. Both graphs are constructed on the same vertical scale as in the previous report. The ordinates in Fig. 1 for each season are the algebraic sums of the ordinates in Fig. 2 for that season.

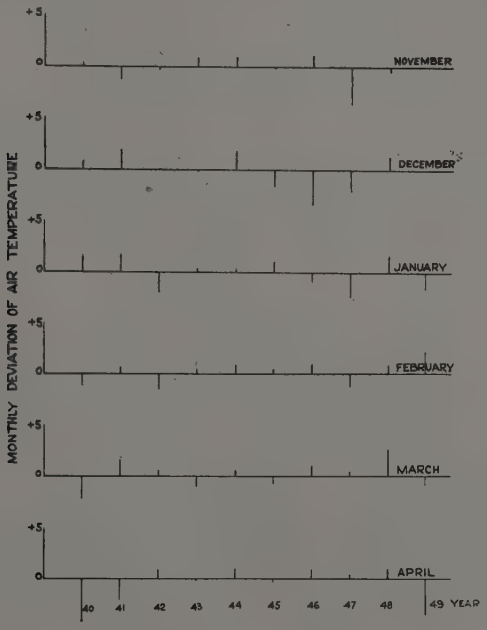


FIG. 2

CONCLUSIONS

A glance at the graphs in the previous publication clearly shows that the outstanding deviations occurred during the 1935 and 1938 seasons. When the graphs for the period 1940-48 are compared with the earlier ones, it is at once obvious that at no time during the recent period were the positive deviations nearly as great as in those two outstanding years.

TABLE IV. INTEGRATED DEVIATIONS OF AIR TEMPERATURE. NOVEMBER TO APRIL, INCLUSIVE

Station	Season									
	1939/40	1940/41	1941/42	1942/43	1943/44	1944/45	1945/46	1946/47	1947/48	1948/49
Te Paki	-8.6	-2.9	-2.8	-2.2	--	-3.3	-3.8	-3.2	--	--
Auckland	-6.1	+3.1	-1.3	+1.8	+8.1	-4.3	-1.0	-8.8	+3.6	-3.7
Maioro	--	+3.2	-1.1	+1.7	+5.2	-0.6	+1.3	-8.2	+8.9	-2.8
Waihi	-7.3	+0.5	-2.4	-1.8	+6.7	-3.5	+1.4	-6.2	+10.9	-7.6
Te Aroha	-6.3	+1.1	-0.9	--	+5.6	-1.5	+5.6	-5.8	+5.5	--
Tauranga	-3.8	+4.1	0	--	+8.7	-2.5	+3.5	--	+6.8	-2.6
Ruakura	-14.6	-3.4	-5.4	-5.5	+6.3	-6.5	-2.6	-10.9	-2.1	-13.2
Rotorua	-0.3	+9.1	+2.1	+1.0	+6.2	-2.5	+3.0	-4.9	--	--
Whakarewarewa	-5.5		-4.4	+0.2	+3.8	-5.7	0	-5.9	+4.0	-6.2
Gisborne	-7.8	+1.2	+0.3	+2.8	+3.2	+1.0	-2.0	-11.6	-0.2	-4.5
Karioi	-5.4	+1.5	-1.0	--	-6.3	0	+0.9	-7.5	+9.9	+1.8
Napier	-1.9	+0.3	-4.0	+0.4	+4.2	+2.1	+1.9	-11.8	+3.9	-0.8
Hastings	+0.7	+4.4	+1.3	+5.7	+9.0	+4.5	+5.4	-4.0	+3.5	-6.3
Taihape	-4.1	+5.1	-4.5	+2.8	+10.1	-0.7	+2.2	-7.3	+12.5	-1.6
Wanganui	-3.7	+4.7	-1.6	+0.8	+6.5	-0.1	-4.0	--	+6.8	-3.4
Tangimoana	-6.2	+3.5	-1.7	+2.0	+12.0	+3.9	+1.5	-5.5	+14.2	+2.2
Palmerston North	-5.4	+2.3	-5.2	-2.8	+7.3	+0.8	-7.1	-12.4	+7.8	-4.6
Pahiatua	-5.8	+1.2	-6.5	-2.3	+3.8	-2.7	-5.9	-11.8	+6.4	-4.3
Masterton	-1.4	+1.4	-4.3	-0.9	-4.0	-6.8	+8.4	-17.7	+3.8	-6.4
Wallaceville	-1.1	+1.2	-2.4	-0.2	+4.3	+0.6	-3.4	-8.8	+10.2	-1.2
Kelburn	-2.0	+4.2	-3.4	+1.4	+5.8	-1.8	-2.4	-7.9	+8.7	-2.0

NOTE: Blank spaces indicate incomplete temperature recordings.

The evidence here assembled thus tends to confirm the conclusion previously drawn, that high earth and air temperatures are associated with serious outbreaks of facial eczema. There has been no such serious outbreak since 1938, and during this period there has been also no season in which the earth and air temperatures were abnormally high.

ACKNOWLEDGMENTS

Acknowledgments are due to Dr. J. F. Filmer, Director of the Animal Research Division, Department of Agriculture, for the information supplied and to the Director and officers of the Meteorological Office for making available the temperature data used.

Thanks are also due to the Director, Dominion Physical Laboratory, for permission to publish this report.

REFERENCE

(1) COOPER, E. R. and WALKER, D. (1940): *N.Z. J. Sci. Tech.*, *A*, *22*, 30-41.

TABLE V. INTEGRATED DEVIATIONS OF EARTH TEMPERATURE

Station	Season										
	1939/40	1940/41	1941/42	1942/43	1943/44	1944/45	1945/46	1946/47	1947/48	1948/49	Depth
Te Paki	-17.2	-9.0	+1.0	+6.1	--	+3.6	+13.8	+1.3	+7.1	+7.8	1 ft.
Auckland	-8.0	0	+0.3	-2.1	+1.5	-5.2	-3.3	-11.7	+2.2	-6.9	1 ft.
	-7.2	+0.1	-4.3	+3.7	+3.2	-3.4	-6.6	-10.8	-3.5	-7.3	3 ft.
Maioro	--	+5.0	-5.9	-3.0	+6.7	-0.1	-3.0	-7.3	+5.0	-3.6	1 ft.
	--	+5.9	-7.3	-3.3	+1.8	-0.1	-7.0	-6.5	+4.4	-3.1	3 ft.
Waihi	-0.2	+5.3	-2.7	+1.6	+6.0	+3.4	- 2.7	--	-2.7	--	2 ft.
Te Aroha	--	--	-3.2	-0.4	+5.3	-0.2	+1.7	-6.0	+7.4	-5.3	1 ft.
Ruakura	-8.6	-2.8	--	-2.5	+1.6	-0.1	-6.4	-10.3	+5.2	-8.0	4 in.
	-6.7	-0.8	--	-3.4	+2.9	-2.2	-6.5	-8.3	+1.0	-2.1	8 in.
	- 5.5	-1.0	-6.2	-1.6	-0.3	-2.7	-9.3	-10.3	-2.6	-1.9	3 ft.
Gisborne	--	--	--	--	--	+7.0	+6.0	-11.2	+2.7	-8.1	4 in.
	-5.2	+0.9	-6.9	+1.5	+0.9	+4.8	+7.1	-5.0	+12.8	-8.9	1 ft.
	+0.7	+4.7	-6.2	+5.3	+4.3	+4.2	+4.4	-1.5	+11.8	+4.1	3 ft.
Napier	-4.5	+1.5	-6.1	-1.0	+3.0	+0.6	-2.0	-10.0	+1.5	-3.9	1 ft.
	-2.5	+1.2	-6.7	-0.7	+1.1	+2.7	+0.9	-7.7	-1.6	-9.6	3 ft.
Hastings	--	--	--	-0.6	+3.6	-1.0	--	-4.0	+5.8	-10.9	4 in.
	-5.5	-1.6	-9.2	+0.7	+2.0	-3.3	+9.6	-1.3	+9.4	-9.1	1 ft.
Taihape	+2.3	+8.0	+3.8	+8.8	+9.5	+11.3	+0.7	-1.9	+12.9	+4.7	2 ft.
Wanganui	-4.1	-3.8	-10.7	-3.2	+8.2	-4.4	-4.0	-11.9	+6.4	-4.2	1 ft.
	-1.3	+1.9	-11.5	-3.5	+4.0	-4.7	-3.5	-11.7	+3.4	-5.2	3 ft.
Palmerston North	-2.5	-2.4	-7.6	+1.5	+14.6	—	+0.7	-3.4	+11.3	-0.9	4 in.
	-6.1	+1.5	--	—	+8.6	+4.4	+4.0	+1.5	+10.7	+6.8	8 in.
	-5.6	+1.3	-7.5	+3.7	+11.7	+8.6	+0.3	-1.3	+13.2	+4.6	1 ft.
	-4.9	+4.0	-2.3	+4.7	+9.0	+12.4	+4.9	+1.6	+17.1	+12.8	3 ft.
Masterton	+0.3	+3.1	-10.4	+4.0	+11.2	-1.4	+4.5	-7.0	+10.2	-0.9	1 ft.
Wallaceville	-0.8	+1.6	-2.2	-0.7	+4.2	+0.1	-4.4	--	+4.8	--	4 in.
	+0.3	+2.6	-1.9	-1.8	+3.3	+0.2	-3.5	-12.7	+1.2	-0.2	8 in.
	-1.1	+1.8	-3.6	+1.2	+3.7	+0.9	-3.3	-10.5	+5.6	-3.7	1 ft.
	+0.3	+1.8	-2.3	+0.8	+1.0	+0.1	-3.9	-10.0	+2.3	-3.0	3 ft.
Kelburn	—	--	--	--	+12.4	-1.9	-3.3	-7.7	+9.8	-0.7	4 in.
	--	--	--	--	--	+3.0	+0.4	-5.3	+11.1	+1.5	8 in.
	-2.7	+1.8	-5.2	-0.9	+6.6	+4.5	-5.5	-11.0	+5.1	-2.8	1 ft.
	0	+1.4	-4.9	-0.8	+3.2	+1.6	-4.2	-10.3	+5.1	-0.6	3 ft.

NOTE: Blank spaces indicate incomplete records.

GREEN-CRINKLE, A VIRUS DISEASE OF APPLES

By J. D. ATKINSON and R. E. ROBBINS, Fruit Research Station, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 17 January 1950*)

Summary

An apple disease known as green-crinkle occurs in all main fruit districts of New Zealand. Symptoms have been observed only on fruit and it is common to find only a single branch of a tree infected. Although green-crinkle is not a major disease, it has caused appreciable loss in some varieties. It has been shown that the disease can be transmitted from infected trees to healthy scions, and from diseased buds to healthy trees. Green-crinkle appears to be caused by a virus which is probably identical with false-sting reported from Canada.

INTRODUCTION

During a survey of Nelson orchards in 1934, green-crinkle was observed on a number of trees scattered throughout the area. It has been reported previously (Atkinson 1946) that the disease appeared to have been spread by infected scions. Development of fruit symptoms on scions from infected trees topworked on healthy trees in 1939 demonstrated that green-crinkle was perpetuated in the scion. Recent work has shown that the disease can be transmitted from diseased to healthy wood indicating that it is caused by a virus.

SYMPTOMS

Foliage and wood of infected trees appear normal, symptoms being found only on fruit. When infected apples are from $\frac{1}{2}$ in to $\frac{3}{4}$ in in diameter small creases appear on the surface. Owing to uneven growth these fruits become much distorted as the season advances (Fig. 1).

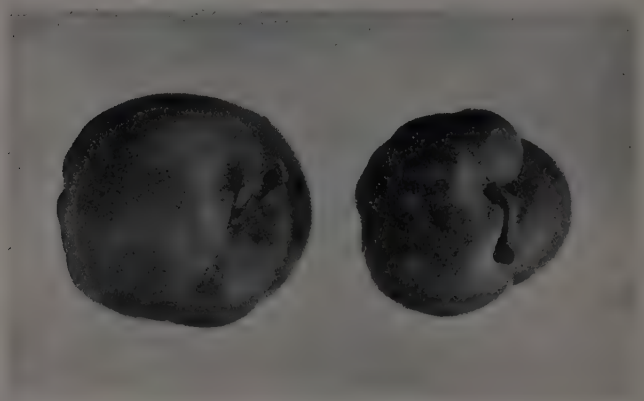


FIG. 1.—Granny Smith apples infected with green-crinkle. (x 9/10)

Photo: L. H. Wright.

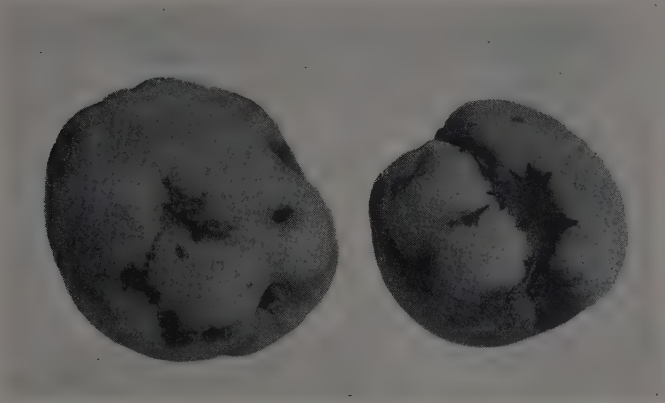


FIG. 2.—Russetting and cracking in depressions caused by green-crinkle on Gravenstein apples. (x 4/5). Photo: L. H. Wright.

Irregular areas of russet or blemish frequently form in the folds, accompanied in some varieties by pronounced cracking (Fig. 2). Where a number of depressions form on one fruit it remains stunted, but where only a single depression develops fruit size is not markedly restricted. Less commonly, infected apples may show a number of irregular wart like swellings, some of which are covered with rough russet (Fig. 3). The two symptoms may occur on separate trees, on the same branch and occasionally together on the same apple.

Below the depressions or swellings the vascular system is distorted and coloured green. This colouring may extend as far as the core zone but is most pronounced immediately below the epidermis. There is no necrotic tissue or pit formation in cortex or core. Infected apples keep as well as healthy ones under orchard storage conditions.

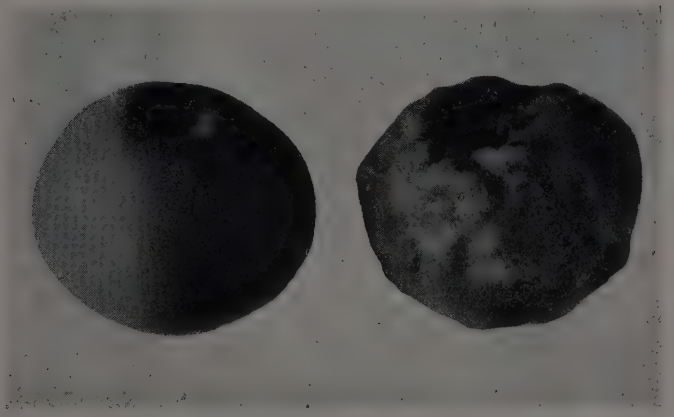


FIG. 3.—A Dunn's fruit showing the swellings occasionally produced by green-crinkle. (x 2/3). Photo: R. I. Hughes.

It is common to find green-crinkle on only one of the main branches of a tree. Field observations indicate that most apples on such a limb show some distortion every year. It has been found that the disease may remain restricted to this one branch for at least ten years. In other cases a small percentage of fruits showing symptoms may be spread over several branches, or every apple on the tree may be affected.

INCIDENCE

Green-crinkle has been found in Auckland, Tauranga, Hawkes Bay, Nelson, and Central Otago. Granny Smith is the most commonly affected variety, but the disease has also been found in Cox's Orange Pippin, Dunn's, Gravenstein, Lord Wolseley, Northern Spy, Statesman and Sturmer. Although the number of trees infected on a single orchard is generally small, the disease is widely distributed in some localities. During 1946, Mr. D. Hogg* made a survey of 61 blocks of Granny Smith apples in the Mapua area, and found infected trees in 39 of these. His survey of this variety covered 8,420 bearing trees of which 574 showed infection.

EXPERIMENTS TO DETERMINE HOW THE DISEASE IS TRANSMITTED

The fact that no pathogenic organisms were found in affected apples suggested that the disease might be caused by a virus. To determine whether transmission to healthy wood could be obtained the following experiments were carried out.

Effect of grafting healthy wood to a diseased tree

In 1946 five leaders of a nine leader Dunn's apple tree in Nelson, that had shown severe infection in a large percentage of fruits for the three previous seasons, were grafted with scions from three healthy Dunn's trees. The remaining branches were left ungrafted as controls. During 1948 these scions bore a few apples some of which showed typical green-crinkle. In 1949 most scions bore apples, and a large percentage of these were infected. Results showed that transmission occurred in each of the five grafted leaders (Table I). Fruit carried on the original wood of the grafted branches, and on the control limbs showed severe infection.

TABLE I. TRANSMISSION OF GREEN-CRINKLE BY GRAFTING HEALTHY DUNN'S SCIONS INTO A SINGLE DUNN'S TREE SHOWING SEVERE SYMPTOMS IN ALL NINE LEADERS. (Five leaders grafted, four left as controls. Crop picked and recorded 5.3.49)

	GRAFTED LEADERS		
Leader No.	Source of healthy scion wood (Tree number).	Number of infected apples on scions.	Total number of apples on scions.
1	23/3	1	15
2	23/3	13	22
3	39/25	13	13
4	39/25	4	5
5	43/25	2	6

*Orchard Instructor, of the Horticulture Division, Dept of Agriculture.

UNGRAFTED LEADERS

Leader No.	Number infected apples per leader.	Total number of apples on leaders.
6	60	71
7	51	83
8	38	115
9	28	47

The total crop of the three trees from which healthy scions had been obtained was sorted on 5 March 1949, and found to be free from symptoms of green-crinkle.

Effect of grafting diseased wood to healthy trees

Each of six Malling IX apple rootstocks was budded with Granny Smith buds from two sources. The upper bud on each stock was obtained from a healthy tree, the lower from an infected tree. In the same way another set of six Malling IX stocks was budded with both diseased and healthy buds of the Dunn's variety. There was one exception in this set, one tree being worked with a healthy Granny Smith bud in place of the healthy Dunn's. To provide controls six healthy trees of each of the two varieties were raised on Malling IX stocks. All 24 trees were set out in the field at Auckland during 1947. In 1949 fruit was produced on most of the trees, and symptoms of green-crinkle appeared.

Five of the six diseased Granny Smith buds grew and each produced typically distorted fruit. On four of these trees green-crinkle appeared in fruit growing on wood from healthy buds. All apples produced on the five branches that grew from diseased Dunn's buds showed the disease. In four trees the disease was transmitted to healthy wood of Dunn's and in one to healthy wood of Granny Smith. Fruit was carried on each of the control trees, all these apples being free from green-crinkle.

IDENTITY

Symptoms of green-crinkle closely resemble those of false-sting, which was recorded and described from Nova Scotia by Hockey (1941; 1943). He obtained transmission from infected scions to healthy trees, and concluded that the disease was of virus origin. The fact that green-crinkle can be transmitted by both grafting and budding indicates that a virus is the cause. The similarity of symptoms and method of transmission suggest that false sting and green-crinkle are closely related, if not identical.

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FUSARIUM-FOOT-ROT OF PEAS IN NEW ZEALAND

By I. A. M. Cruickshank, Plant Diseases Division, Department of Scientific and Industrial Research, Christchurch

(*Received for publication, 17 February 1950*)

Summary

1. Fusarium-foot-rot (*Fusarium solani* var. *martii*) is recorded as occurring in pea-growing districts in New Zealand, its characteristic symptoms being seed-decay, pre-emergence rot, seedling-rot, and foot-rot.

2. Morphological characteristics are identical with overseas descriptions of *F. solani* var. *martii* f.2.

3. Each of the 21 varieties of peas tested were found susceptible to fusarium-foot-rot.

4. In tests as seed-dressings at one and two ounces per bushel, Spergon, Phygon, Arasan, Ceresan N.I., Agrosan G.N., Nomersan and Cupric carbonate failed to control the disease.

Introduction

Fusarium-foot-rot (*Fusarium solani* Mart. var. *martii* (Appel et Wollenw.) forma *2* Snyder)* has been observed affecting pea crops in Canterbury, Marlborough, Hawkes Bay and Auckland, although recent annual surveys in these districts have not revealed serious crop losses due to this disease. Jones (1923) first described fusarium-foot-rot of peas and it has since been recorded in the chief pea-growing areas in both North America and the Continent of Europe (Reinking, 1942; Janssen, 1949).

Symptoms

Fusarium solani var. *martii* causes seed-decay, pre-emergence and seedling-rot, and foot-rot. Symptoms on maturing plants are characterized by a dark-reddish brown or chocolate coloured lesion (Fig. 1) accompanied by a deep cortical rot (Fig. 2). Lesions may be approximately one to three inches in length and at their upper limits are wedge-shaped. At their base they may completely girdle the stem and extensively infect the main root system. Cortical rotting may be accompanied by a deep red discolouration of the stele near the hypocotyl. Wilting and death of plants results when cortical rotting is extensive.

Identity of New Zealand Organism

Morphology

Measurements were made from cultures grown on potato dextrose agar of the following composition:—

Potato, 200 g.; glucose, 15 g.; agar, 16 g.; water, 1000 ml.

Macroconidia (Fig. 3a)

2-septate: rare: 25.0 - 27.5μ x 3.75 - 5.0μ.
3-septate: abundant: 25.0 - 42.5μ x 4.5 - 5.0μ.
4-septate: abundant: 32.5 - 57.5μ x 4.5 - 5.5μ.
5-septate: very rare: 44.0μ x 5.5μ.

* The author is indebted to Dr W. C. Snyder, University of California, United States of America, for confirmation of this identification.

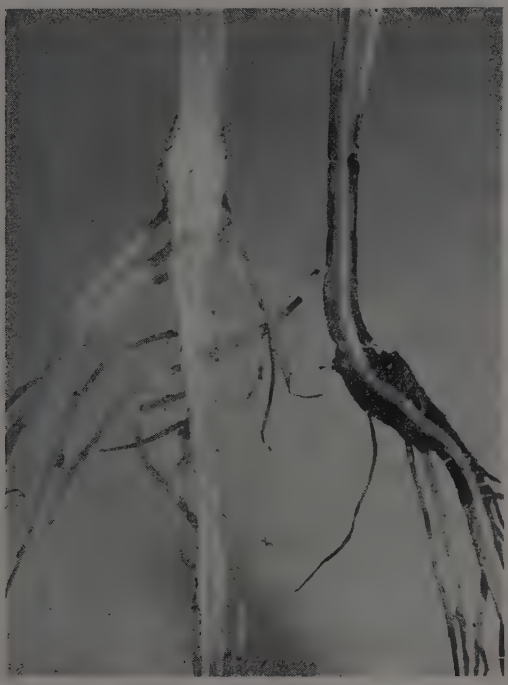

FIG. 1.—Foot-rot lesions on pea-stems (healthy plant on left).
Photograph by R. I. Hughes.

FIG. 2.—Longitudinal section of foot-rot lesion (healthy plant on left).
Photograph by R. I. Hughes.

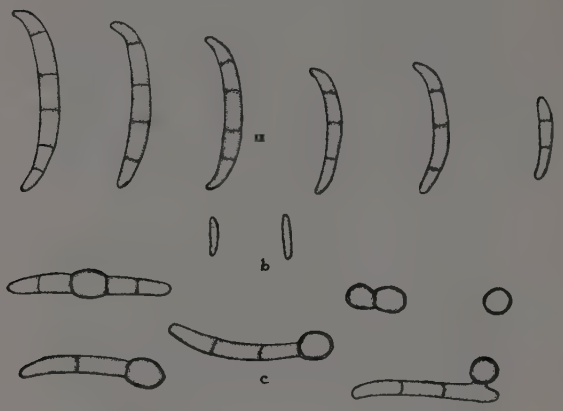

FIG. 3a.—Macroconidia of *Fusarium solani* v. *martii*.
b. Microconidia of *Fusarium solani* v. *martii*.
c. Chlamydospores of *Fusarium solani* v. *martii*.

Microconidia (Fig. 3b)

0-septate: abundant: 7.5 - 12.5μ x 2.5 - 3.75μ.
1-septate: very rare: 9.0μ x 3.75μ.

Chlamydospores (Fig. 3c)

On mycellium or macroconidia, intercalary (daliform) or terminal (globose to obovoid) 6.25 - 8.75μ x 10.0 - 11.25μ, occurring usually singly, rarely in pairs, very rarely in chains or clusters.

Cultural characters

When grown on potato dextrose agar the following characters of the fungus were observed: growth zonate; aerial mycellium short, greyish white, sparse; macro and microconidia produced abundantly in zinc to prussian blue coloured sporodochia and pseudopinnotes; substrate colour vinaceous.

Pathogenicity

The variety Onward was sown in soil artificially inoculated with *F. solani* v. *martii*. When examined six weeks to two months after sowing the plant roots showed fusarium foot-rot symptoms. *F. solani* v. *martii* was reisolated from all plants sown. In clean soil plants of the same variety remained healthy.

EXPERIMENTAL METHODS

Varietal Resistance Tests

The 21 varieties of peas listed below were grown under heated glasshouse conditions, in artificially inoculated soil to test their resistance to fusarium foot-rot. Six pot replicates of each variety were included in two trials.

Garden varieties.—Blue Bantam, English Wonder, Green Crop, Greenfeast, Giant Stride, Laxton's Progress, Little Marvel, W. F. Massey, Onward, Pioneer, Senator, Stratagem, Thomas Laxton, Yorkshire Hero.

Field varieties.—Blue Prussian, Harrison's Glory, Mammoth Blue, Mammoth, White, Marathon, Partridge, White Prolific.

Seed-dusting Trials

The efficacy of seed-dressing under conditions of heavy soil infection was determined in glasshouse and field-plot trials in which seed of the variety Greenfeast was dusted with the following proprietary seed-dressing materials at the rates of one and two ounces per bushel: Spergon (98 per cent tetrachloro parabenzoquinone), Phygon (98 per cent 2, 3 dichlor 1, 4 naphthoquinone), Arasan (50 per cent tetramethyl thiuram disulphide), Ceresan N.I. (5 per cent ethyl mercury phosphate), Cupric carbonate (53.5-56 per cent Cu) and Agrosan G.N., and Nomersan (undisclosed formulations).

Plants were examined after two months for fusarium foot-rot symptoms. At least 90 per cent of the plants in each treatment showed foot-rot lesions while all plants from undusted seed were infected.

CONCLUSIONS

Under the conditions of the above experiments, viz. soil heavily inoculated with *F. solani* var. *martii,* no variety tested showed resistance to fusarium foot-rot and none of the seed-dressings tested proved effective in its control.

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SOILS OF SOUTH-WESTERN SOUTHLAND

By A. C. S. Wright, Soil Bureau, Department of Scientific and Industrial Research, Wellington

(*Received for publication, 22 November 1949*)

Summary

A soil reconnaissance of south-west Southland has established that there is little land of agricultural value in this rather inaccessible region.

The dominant soil processes are podzolization and gleying, and the main soil types are gley podzols, resembling the "Pakihi" land in Westland. Zonal peat is developing over part of the area.

The general condition of the *Nothofagus* forest in the region is poor and it is suggested that this can be correlated with deteriorating soil conditions.

Introduction

A soil reconnaissance was carried out from 13-20 January, 1949, in the coastal district of south-western Southland extending from Port Craig to the mouth of Big River which drains Lake Hakapoua.

The main geomorphological feature of this district is a coastal shelf consisting of at least three terraces extending from one to three miles inland. The lowest terrace lies at 60 to 100 feet above sea-level and has a flat to undulating surface relatively little dissected except for a few large streams. Coarse bouldery gravels, mainly gneiss and granite, cover this terrace to a depth of from 10 to 40 feet, the underlying mudstone, sandstone, or gneiss being exposed only in the more deeply entrenched streams. Near the coast, the gravels themselves are commonly overlain by as much as four feet of a finer deposit—closely resembling the "loess-like" material recorded elsewhere in Southland.

Other terrace levels occur at 100 to 300 feet above sea-level, and again at 600 feet to over 1,000 feet above sea-level. These, also, are mainly covered with gneissic gravel, but in places they are deeply dissected by streams so that the gravel overburden now lies only on the ridge tops and in the valley bottoms. Inland from the region of coastal terraces the country is very broken in relief and rises gradually to the peaks of the Cameron Mountains and the Princess Range (4,000 to 5,000 feet in height): the Hump Range, which lies immediately north of Port Craig, rises to a little over 3,500 feet directly from the coastal terrace system.

The greater part of the coastal shelf has been carved from a blue-grey mudstone of Tertiary age. This rock is also present in the foothills where it lies directly in contact with the gneiss of the Fiordland complex. Limestones and Coal Measure sandstones occur on the Hump Range, and reappear again further west in the vicinity of Mt. Bates. They are mainly well-dissected by streams and fall into the categories of hilly or steep land, although at lower altitudes there are occasional broad ridges covered with gneissic gravels. Gneiss and related rocks of the Fiordland complex occur west of the Fiordland fault which traverses Lakes Poteriteri, Innes and Hakapoua.

The climate is predominantly cool and moist. There are no permanent rainfall stations in the area, but it is probable that the annual rainfall is in excess of 80 inches, distributed evenly over 175 or more rainy days. The eastern portion of the coastal strip (Port Craig to Francis Burn) may be slightly drier than the rest of the district examined.

The area is almost entirely forest covered. There are felled clearings in the vicinity of Port Craig, small areas of sphagnum bog further to the west, and tussock-covered slopes lying to the north; all these areas are, however, of relatively small extent. The forest undercanopy has probably been very considerably modified by the activities of deer and pigs, which are numerous. The commonest large tree is undoubtedly *Nothofagus Cliffortioides*, and this is the dominant species over wide tracts on the coastal shelf. Large specimens of *N. Menziesii, Dacrydium cupressinum, Podocarpus ferruginosus* are scattered throughout the region and attain local dominance in certain situations. *N. Menziesii* forest, for instance, is commonest on hilly land where the underlying rock is slightly calcareous. *Weinmannia racemosa* is a very common tree, but few large specimens were seen. *Metrosideros lucida* is locally dominant on the coast, and reappears again inland on the foothills. With the exception of the valley bottoms and river delta systems, the forest is fairly open, with few scrub species and a dense ground cover of fern (*Blechnum* spp.).

From the size and appearance of the dominant trees, the general age of the forest appears to be young. The percentage of dead and dying trees seems unusually high. There are often many moribund specimens, trees which, by comparison with other localities in Southland, should be nearing their prime. The impression gained from a casual examination of the area was that each successive generation of trees was succumbing at an increasingly early age. Early symptoms appear to be wilting and yellowing of the terminal foliage, leading to a "stag-headed" appearance which persists until the tree is decapitated or overturned by a gale. Such symptoms suggest some pathological or physiological root trouble. Overturned trees commonly exhibit an extremely shallow rooting system. This observation applies to almost all species, including *Metrosideros*. Symptoms which appear to precede the death of the tree were also observed in all species mentioned.

The zonal soils of the area are podzolized yellow-brown earths, podzols, and podzolized gley. Intrazonal soils are confined to small patches near the coast, derived from dune sand and igneous breccia with local gley soils developed in the valley bottoms. Azonal soils are mainly developed in the western part of the region (skeletal soils on very steep slopes), and small scattered areas of soil derived from recent alluvium occur in association with the river systems. (Fig. 1.)

Zonal Soils

1. *Gley podzols of the coastal shelf, and river terraces*

The main soil type on all terrace levels of the coastal shelf is a gley podzol which in many respects resembles the "pakihi" of the West Coast region. Profiles are characterized by a deep A horizon, always peat stained and brownish-grey in the natural state, and a well defined, gleyed, B_1 horizon underlain by a strongly cemented iron-pan in the B_2 horizon. There are three main variants of this profile according to the

micro-relief and local drainage. Where the surface is slightly convex, the iron-pan is more pronounced and the subsoil has a marked orange or rusty colour; where the surface is flat or slightly concave, the subsoil gleying is more prominent, the iron-pan frequently diffuse, and orange mottling less prominent. In both of these variants the water-table lies at from 7 to 14 inches below the surface in a normal season, descending to 18 inches during a prolonged dry spell, but rapidly rising to and remaining at the surface during heavy rain. The pattern made by these two variants is necessarily complex and it is unlikely that they will ever need to be mapped separately. Where these soils occur on an extensive flattish surface, conditions have become so wet that "bog forest" with dominant *Dacrydium* sp. is well established and the profile is becoming buried under an accumulation of sphagnum peat. These areas can be mapped readily from air photos, and the soil has been mapped as a peaty phase.

The poorer drained variant of the gley podzol shows the following profile:—

4 in mixed litter forming a reddish-brown fibrous loamy peat (A_0);

7 in dark greyish to brown-grey crumbly sandy loam (A_1);

4 in light brownish-grey moist, moderately compact sandy loam, dries as very pale grey (A_2G);

5 in pale grey compact loam with a weak brown, or orange, mottle (B_1G);

7 in dark brown coarse sandy loam, weakly cemented and laminated (B_2G);
on compact gravelly sand, pale yellowish grey weakly mottled orange and dark brown, blotchy appearance (C).

(Water-table at 12 inches, but normally much closer to the surface. Angle of slope about 2°. Locality: middle terrace, east bank Wairaurahiri River. Vegetation: *N. Cliffortioides* dominant.)

The better drained variant shows the following profile:—

2 in red-brown fibrous loamy peat;

6 in grey sandy loam with brownish peat staining;

5 in very light grey stony sandy loam, weakly cemented;

2 in orange and brown compact coarse sandy and gravelly loam;

¼ in iron-pan cemented around gravel;

2 in gravelly sand and boulders, cemented by iron-humus pan: on pale greyish yellow bouldery gravel, weakly cemented in part.

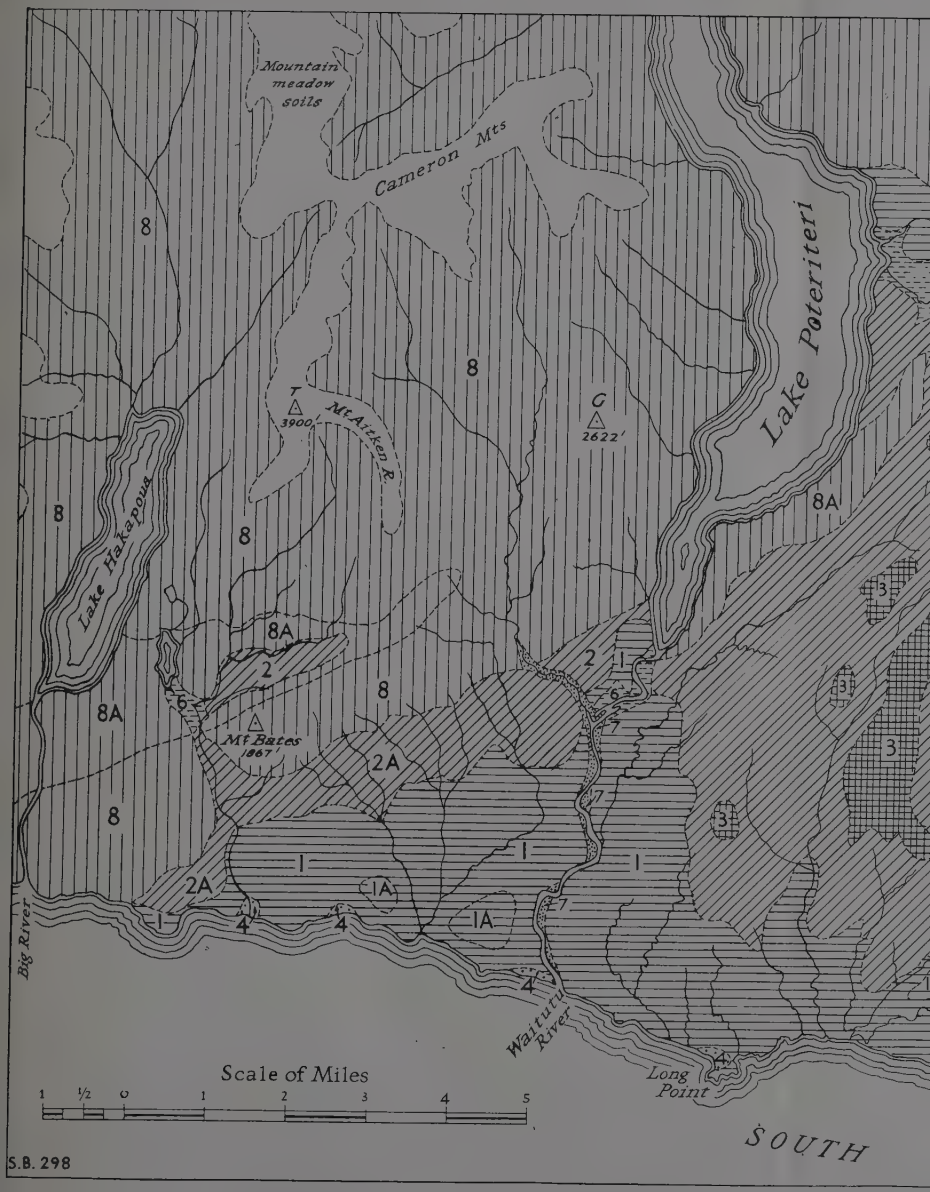
(Angle of slope: 2°. Locality: middle terrace, E. bank Wairaurahiri River. Vegetation: *N. Cliffortioides*, etc.)

The peaty phase has the following profile:—

7 in mixed *Dacrydium* leaf litter and sphagnum moss;

10 in pale brownish loamy peat;

11 in light grey or pale brownish-grey smooth silty clay loam;
on yellowish grey, mottled dark brown and yellow gravels with fragmental sections of cemented iron-pan.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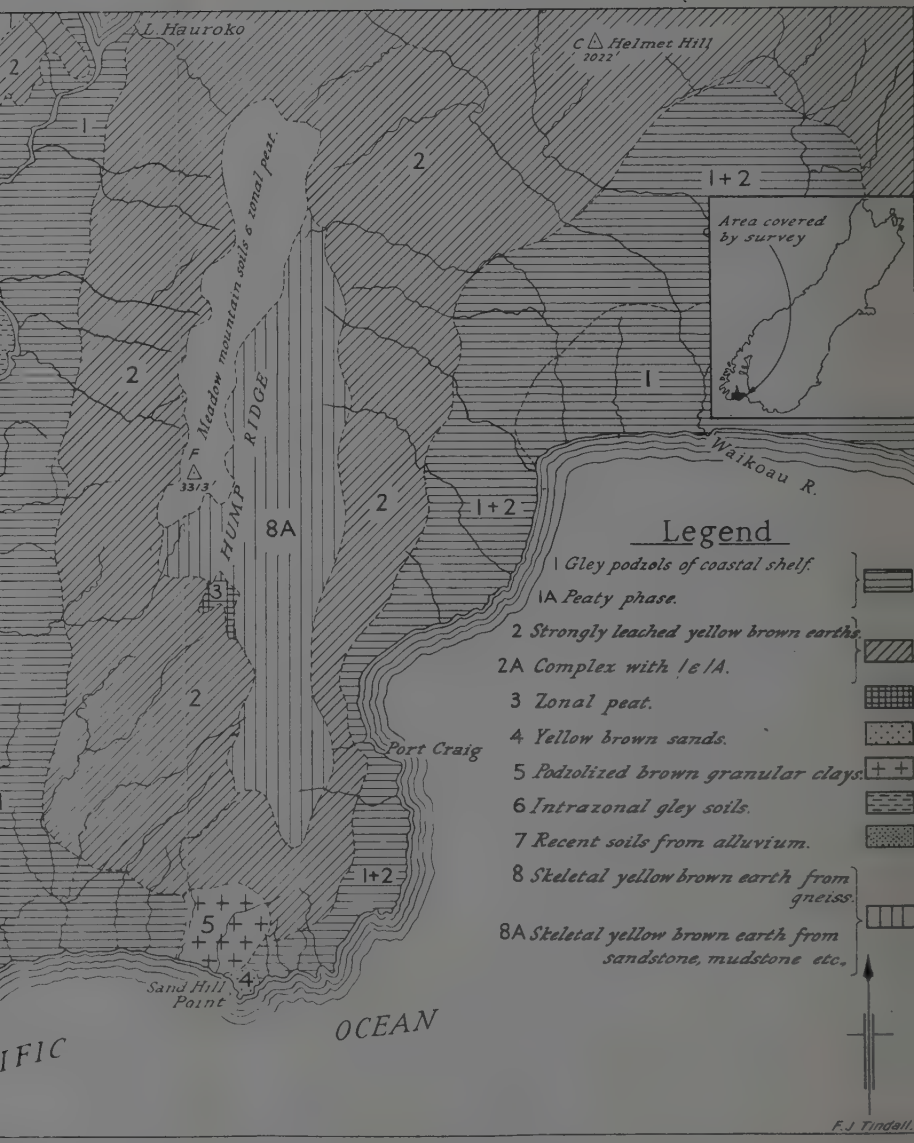
L. Hauroko
C △ Helmet Hill 7022'
Meadow mountain soils & zonal peat.
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HUMP
F △ 3313'
8A
Area covered by survey
Waikoau R.
Port Craig
Sand Hill Point
OCEAN
IFIC
Legend
1 Gley podzols of coastal shelf.
1A Peaty phase.
2 Strongly leached yellow brown earths.
2A Complex with 1 & 1A.
3 Zonal peat.
4 Yellow brown sands.
5 Podzolized brown granular clays.
6 Intrazonal gley soils.
7 Recent soils from alluvium.
8 Skeletal yellow brown earth from gneiss.
8A Skeletal yellow brown earth from sandstone, mudstone etc.
F.J. Tindall

thland

FIG. 2.—Gley podzol profile development in loess-like material on coastal shelf near Francis Burn, showing deep accummulation of litter under *Weinmannia racemosa.*

A fourth profile, common on the terraces near the coast is prominently displayed along the cliff-edge from Sand Hill Point to the Waitutu River. The soil has developed from "loess-like" material overlying the gravels and has the following profile:—

10 in reddish loamy peat (mixed *Metrosideros, Weinmannia,* and *Nothofagus* litter);

15 in dark (purplish) brown, crumbly and granular peaty silt loam (when dry: 4 in dark grey granular silt loam, 11 in whitish to pale-grey fine granular silt loam);

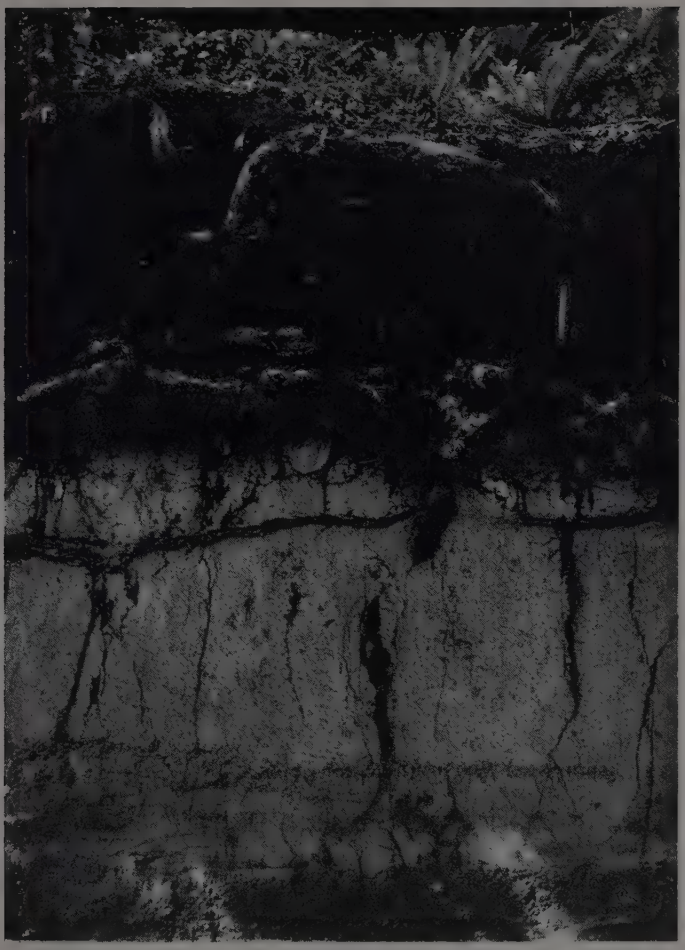

FIG. 2.—Gley podzol profile development in loess-like material on coastal shelf near Francis Burn, showing deep accummulation of litter under *Weinmannia racemosa*.

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15 in dark (purplish) brown, crumbly and granular peaty silt loam (when dry: 4 in dark grey granular silt loam, 11 in whitish to pale-grey fine granular silt loam);

⅛ to ¼ in orange-brown cemented iron-pan (not everywhere continuous);

8 in pale brownish-yellow compact silty clay loam; on pale brownish-yellow gravelly sand.

(Angle of slope: 20°. Locality: coast near Angus Burn. Vegetation: coastal forest.)

The appearance of the soil profile is radically altered by exposure and drying out. In dry profiles exposed along the cliff edge and in cuttings along former mill tramlines a bleached A_2 horizon can be seen separating the dark granular topsoil from a weakly developed iron-pan in the B_2 horizon. There is usually little sign of any zone of humus accumulation above the iron pan.

2. *Strongly leached Yellow Brown Earths of the foothills*

These soils are derived from Tertiary mudstone, sandstone, limestone and conglomerate occurring on the Hump Range, the high country adjacent to Mt. Bates, and on the slopes of the ravines cutting through the coastal terraces. With detailed mapping these soils would be split into types relating to soil parent material, but on a reconnaissance basis it is more useful to group them all together because of the similarity of their respective profiles. For the most part they are hill profiles although "normal" profiles are found locally on ridges. A typical profile developed on a flattish ridge in soil derived from calcareous mudstone shows:—

4 in reddish-brown fibrous loamy peat (mainly *N. Cliffortioides*);

5 in dark purplish-brown loam (peaty);

7 in light grey silty clay loam;

3 in dark brown peaty clay loam;

1 in orange-brown silty clay loam with a well-cemented iron-pan; on pale yellowish-brown clay loam with mudstone fragments.

(Angle of slope: 5°. Locality: one mile N.E. of Mt Bates. Vegetation: *N. Menziesii, N. Cliffortioides,* etc.)

The associated hill soils show a similar, but shallower, profile:—

3 in brown fibrous loamy peat;

3 in very dark brown peaty loam;

2 in pale greyish-brown loam;

1 in dark brown peaty loam;

½ in orange-brown mottled dark brown silty clay loam; on yellowish, mottled brown and orange fine sandy clay loam.

(Angle of slope: 25°. Locality: one mile E.S.E. of Lake Innes. Vegetation: *N. Menziesii,* etc.)

Between the Wairaurahiri and Waitutu rivers there is an area of dissected high terrace, in places but thinly covered with gneissic gravels, so that the underlying mudstone gives rise to much of the soil, particularly on the slopes. This soil complex has been shown on the map as 2a. The component parts of the complex are gley podzols and leached

yellow brown earths, with widespread development of profiles of mixed origin:—

2 in mixed litter—fibrous peat;
3 in dark grey-brown stony sandy loam;
2 in white coarse sand;
5 in very dark brown sandy clay loam;
3 in orange and brown mottled sandy clay loam;
on pale greyish-brown mottled yellowish-brown silty clay loam.

(Angle of slope: 19°. Locality: west bank of Wairaurahiri River. Vegetation: *Weinmannia racemosa, Dacrydium cupressinum.*)

3. *Zonal Peats*

Small areas of peat have developed on flat terraces. Probably this peat is a true zonal peat and not intrazonal as is usually the case elsewhere in New Zealand. The peat (largely derived from sphagnum moss) appears to accumulate rapidly, but as yet no great depth has formed. A profile shows:—

5 in green (growing) sphagnum moss;
8 in pale greyish-white fibrous peat, slightly gelatinous;
12 in light brownish spongy peat, slightly laminated;
10 in brown gelatinous loamy peat;
on cemented white gravels.

INTRAZONAL SOILS

4. *Yellow Brown Sands*

Intrazonal soils derived from blown sand occur at Sand Hill Point and Long Point. They are of small extent. The sand is, for the most part, actively blowing, but areas of moderately well consolidated sand exhibit the following profile:—

6 in dark grey sand;
4 in light brownish sand;
on pale bluff sand.

(Angle of slope: 7°. Locality: Sand Hill Point. Vegetation: sand grasses.)

5. *Podzolized Brown Granular Clays*

Intrazonal soils derived from a coarse reddish breccia are developed over a small area near Port Craig. They may be recognized by their pinkish-brown colour in the subsoil and their granular structure throughout the profile. They are all fairly well podzolized. A typical profile shows:—

12 in dark brown laminated fibrous loamy peat (*Wienmannia*);
3 in dark brown granular peaty loam;
3 in pale grayish brown (peaty) sandy loam, granular;
2 in dark brown peaty sandy loam, coarsely granular;
3 in orange-brown mottled, partly cemented, coarse sandy loam;
on reddish to pinkish-brown, or bright yellow-brown sandy clay loam, often stony.

(Angle of slope: 5°. Locality: 1½ m. N.W. of Sand Hill Point. Vegetation: *Weinmannia* and *Metrosideros.*)

6. *Gley Soils*

Intrazonal gley soils occur in almost all the main valley bottoms, but it is difficult to separate them from zonal podzolized gley on preliminary reconnaissance. A similar difficulty arises along the foot of all the main terrace slopes where local drainage from above assists in producing wet and swampy conditions. Some fairly extensive areas of meadow soil occur in the Crombie depression, but almost all these are more or less peaty and are associated with small patches of intrazonal peat. The soils in this category thus embrace a wide range of profiles ranging from gley to true organic soils. Perhaps the commonest profile shows:—

8 in dark brown wet (peaty) loam;

10 in pale brownish grey smooth and wet silty clay loam with faint brown blotching;

9 in greenish-grey clay loam, moderately compact; on to gravels at about 4 feet.

(Locality: Upper Aan Valley. Vegetation: *Pod. dacrydioides,* etc.)

Azonal Soils

7. *Recent soils from alluvium*

In this category are grouped all the soils derived from recent alluvium. Such soils occur only in relatively small strips alongside the larger rivers and streams. Their textures are varied. In two cases there is a sharp change in texture half way down a valley, due to the entry of a very active side stream bringing coarse gravels from an active fault zone not tapped by the larger stream. These alluvial soils are usually completely covered with a dense forest composed of many tree species, laced through with lianes and supporting a dense fern growth. One selected profile shows the following:—

4 in light brown loamy sand, moderately peat stained;

8 in brown mottled loamy sand; on darker brown peat-stained loam.

(Locality: Lower Waitutu River.)

8. *Skeletal Yellow Brown Earths*

These include the skeletal soils which are developed on steep to very steep slopes in the northern and western portion of the region examined. They are mainly derived from gneiss and related metamorphic rocks, although small areas of Tertiary mudstone, sandstone, and limestone have a similar topography and show skeletal soils. These latter have a slightly higher fertility than those which are derived from gneiss, and have been mapped separately as category 8a. A typical profile developed from gneiss shows:—

1 in mixed litter (mainly *Hymenophyllum* sp., *N. Menziesii,* and moss);

1 in dark brown peaty sandy loam;

2 in whitish (slightly peat stained) coarse sand; on gneiss.

(Locality: Northern face of Mt. Bates. Angle of slope: 40°. Vegetation: *Podocarpus hallii, Archeria* spp., etc.)

Whereas a profile common on the steep tertiary beds shows:— (8a)

½ in mixed fibrous peat;
1 in dark brown loamy sand;
3 in pale greyish sandy loam;
1 in orange-brown loamy sand;
on rubbly sandstone.

(Locality: N.W. shore Lake Innes. Angle of slope: 38°. Vegetation: *Metrosideros, Weinmannia,* etc.)

DISCUSSION

Soil Fertility

There do not appear to be any very fertile soils in the area reconnoitred. The soils of the river valley are of only moderate fertility, and in addition they are very swampy, mainly owing to the high rainfall and lateral drainage from the terrace slopes that flank them. There are no extensive areas of this soil suitable for development.

The gravel-covered terraces are closely similar to the "pakahi" soils near Greymouth, and removal of the existing forest cover might lead to a sharp rise in the level of the water-table with widespread development of bog conditions. These soils are likely to have a very high lime and phosphate requirement, and are copper- and probably cobalt-deficient.

The gley podzols of the coastal shelf are all soils of low natural fertility but in some places they could be drained, and if treated with heavy dressings of lime and phosphate they might carry reasonable dairy pastures. However, they do not warrant development at the present time as they are remote from existing roads, while shelter from the southerly gales would be hard to contrive.

Worms are only occasionally encountered. A number of specimens were collected and these have been identified by Mr. K. E. Lee of the Soil Bureau as belonging to the genus *Octochaetus*. *O. thomasi,* (Beddard, 1892), and *O. huttoni* (Beddard, 1892), were collected from an intrazonal yellow brown sand at the mouth of the Angus Burn, and the same species were also collected from strongly leached Yellow Brown Earths of the foothills in soils derived from either sandstone or mudstone parent material. *O. thomasi* and *O. huttoni* have been recorded previously only from Albury, in South Canterbury, about 200 miles from the region investigated.

The available copper in a wide range of soil samples has been investigated by Mr. D. Breen of the Soil Bureau, using bio-assay techniques. He reports that most soils are markedly deficient in available copper. In this respect they resemble the "pakahi" soils of Westland and some of the "gumland" soils of North Auckland. Only soils mapped as 2A, 5 or 6 have adequate available copper for normal nutritional requirements.

Of the hilly country, only the small area mapped as category 2 has sufficient fertility to hold grass, and these fertile pockets are by far the most unstable; even under the existing forest cover slips are frequent and extensive. The more stable sandstone slopes are too leached to carry a pasture without additional topdressing, etc.

This picture of uniform low soil fertility is undoubtedly the combined effect of a high rate of leaching with relatively low rate of rock weathering.

Soil Genesis

The trend of soil development would appear to be towards gley formation on all but the moderately steep and steep slopes. The development of small areas of zonal peat on the flat terraces is probably an indication of the general trend of soil formation; the process appears to be a current one. There is some soil evidence in support of a gradual rise in the water-table over most of the terrace area.

The region differs remarkably from the adjacent Fiordland region by virtue of the face that there is a lesser degree of litter accumulation. Only under the large trees is there anything approaching a mound of litter (Fig. 2), and the average depth of "mor" is only 5-6 in, in contrast to an average depth of 2-3 ft on soils with similar topography in the Fiordland region. Removal of most of the undercanopy by deer grazing does not entirely account for this difference, as the plants that have been eaten out are not those species which contribute most towards "mor" formation.

Soil-Plant Relationships

No conspicuous relationships were found between plant associations and any particular pattern of soil condition, apart from the bog forest on the terraces and the *Fuschia-Coprosma-Melicytus-Plagianthus* shrubbery on young soils developing where there has been slip erosion of soils derived from calcareous rock.

The generally poor condition of the forest on the terraces might, in part, be attributed to worsening soil conditions. In the opinion of the writer, this is a natural process and its influence on the forest is as follows:—

Many of the species have become very shallow rooted in habit. This makes for insecure anchorage, and at the same time the trees will suffer should there be any marked defection from the normal rainfall. During a dry period, or a dry season, in which the water-table "perched" above the "B" horizon dries up, large trees have no means by which they can reach the true water-table located at 8-10 ft below the surface and so suffer from drought. Thus a small increase in the variability of the rainfall, without any appreciable decrease in total rainfall, can result in the death of large trees growing in this type of soil. In time this leads to a gradual opening up of the forest canopy which in turn helps to accentuate wet soil conditions when the rainfall returns to normal, because there is a reduction in soil moisture lost through transpiration. Thus the overall result is a gradual rise in the "perched" water-table, which further restricts the rooting of successive generations of trees so that they, in turn, are even more dependent upon even rainfall distribution and any brief departures from the normal lead to early death and to continual degeneration of the canopy. The health of the trees is also affected by the restricted volume of soil from which the roots draw nourishment. In agreement with this hypothesis is the observed fact that the size of the trees and the amount of regeneration improved proportionately as the slope of the ground increased.

ACKNOWLEDGMENTS

The reconnaissance was made possible through the co-operation of the Director of the New Zealand Geological Survey who had field parties under Messrs. A. Beck and B. Wood operating in this rather inaccessible part of New Zealand. The Soil Survey party, consisting of the author and Mr. R. H. Thornton, were allowed unrestricted use of the Geological Survey camps and supply lines—a courtesy which was very much appreciated.

PRELIMINARY NOTE ON YELLOW-LEAF DISEASE OF PHORMIUM

By S. W. BOYCE,[1] W. R. BOYCE,[1] E. E. CHAMBERLAIN,[2] R. A. CUMBER,[2] P. R. FRY,[3] R. E. F. MATTHEWS,[3] F. J. NEWHOOK,[3] and K. STRZEMIENSKI,[4] Department of Scientific and Industrial Research

Attention was first drawn to yellow-leaf disease of Phormium by outbreaks in the Manawatu *Phormium* areas some forty years ago, following extensive exploitation of indigenous induced stands for the *Phormium* fibre industry. The disease is characterised by abnormal yellowing of leaves, stunting of growth, and premature flowering; other symptoms are discolouration of vascular bundles in the rhizome, root death and rhizome rotting, leading to wilting and collapse of the leaves, the invasion of all parts by secondary organisms, and finally disintegration and death. From the appearance of the first symptoms to the final collapse the course of the disease may take from a few months to several years.

Surveys have shown that the disease is present in both the North and South Islands of New Zealand, but it is much more prevalent in the North Island; its incidence is higher in natural stands of *Phormium tenax* Forst., than in those of *P. colensoi* Hook.f., though both species are affected. A long standing and well substantiated observation is that outbreaks of the disease have followed extensive draining and protection from flooding of *Phormium* stands.

Accurate assessments of economic losses due to the disease are unobtainable; it is known, however, that the inroads of yellow-leaf were responsible in part for the deterioration and eventual disappearance of many thousands of acres of induced *Phormium* in the Manawatu district. At the present time it threatens the production of half the remaining *Phormium* producing areas in the North Island.

Equally serious have been the limits set by the disease to efforts to domesticate the plant, in the course of which attempts to improve fibre production by selection, breeding, and improved cultural methods, have been nullified by the disease. Particularly has this been so on the Moutoa *Phormium* area, Foxton, where since 1940 the New Zealand Government has linked development and research to maintain a source of fibre.

Since its first appearance, numerous investigations into the nature of the disease have been carried out; in these, fungal, bacterial and virus pathogens have been postulated and physiological factors considered, but the actual cause has remained obscure, until recent work, reported briefly here, provided virtual proof of its virus nature.

In all earlier investigations, the main obstacle to progress has been failure to transmit the disease or to induce recovery in diseased plants. The failure of numerous attempts to find a fungal, bacterial, or physiological cause, indicated the possibility of yellow-leaf being a virus disease.

Chamberlain in September, 1947, working with mature *P. tenax* plants, obtained several apparently successful root grafts between diseased and healthy plants. Three healthy plants showed symptoms of disease by March, 1950. This result is not inconsistent with the existence of a latent period of up to three years suspected from field evidence.

Fry, Matthews and Newhook in November, 1949, set up mechanical transmission trials using the carborundum abrasion technique on eighteen months old *P. tenax* seedlings. A high percentage of transmission was obtained, symptoms showing in some plants after four to six months and in others after sixteen months.

Insect transmission was first obtained by Cumber who, after detecting the presence of an endemic plant hopper, *Oliarus atkinsoni* Myers. (Hem. Cixiidae) in large numbers at Moutoa, initiated transmission experiments on 2 December, 1949. He used adult hoppers collected in the field from diseased plants, and applied them to seven-to-eight months old *P. tenax* seedlings. A high percentage of transmission was obtained; excessive leaf yellowing was apparent in from four to seven weeks, and on final examination (24/5/51) sixteen out of twenty test plants showed typical internal symptoms of yellow-leaf.

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This result was confirmed by Fry, Matthews and Newhook in a trial with eight months old seedlings set up at Auckland on 16 December, 1949, using adult *O. atkinsoni* from the same area at Moutoa as those used by Cumber.

Cumber established further large scale transmission trial in December, 1950, using eighteen months old seedlings. Fry, Matthews and Newhook in January, 1951, set up an extensive trial in which hoppers from an apparently yellow-leaf free area near Kaikohe were used as checks. These experiments confirmed transmission of the disease and showed that the symptoms obtained were not likely to be due to insect feeding toxicity.

Transmission trials with other insects and other possible host plants have so far given negative results. In some such trials set up in Auckland to test transmission by thrips, mealy bugs and aphids, the aberrant nature of the results did, however, indicate the possibilty of seed transmission of the virus. A high incidence of infection developed in some sets of uninoculated check plants obtained from one seed source; check plants from two other seed sources remained healthy. As plants from all three sources had comparable treatment, the most likely explanation for the appearance of yellow leaf in only one of these, is that some seed transmission had occurred.

Strzemienski used dyes and radioactive phosphate to compare translocation in diseased and healthy plants. In diseased plants, roots translocated dyes and phosphates, and an unimpeded movement of dyes was observed in severed leaves. Yet transfer from roots to leaves was interrupted, presumably in the rhizome.

Newhook extended this work with dyes and showed that this interruption to translocation was caused by xylem gummosis associated with phloem necrosis in the rhizome vascular bundles. These symptoms are at first only demonstrable by staining with phloroglucinol and acid, although in later stages the vascular tissue is visibly discoloured pale yellow to dark red. Their occurrence in leaf and root traces in the rhizome, with consequent hindrance of dye uptake, precedes leaf yellowing and wilting, root death and rhizome rot.

The results of transmission experiments can now be taken as virtual proof that yellow-leaf of *Phormium* is caused by a virus.

The role of *Oliarus atkinsoni* in transmitting the disease may explain the long standing observation that outbreaks of this disease have followed drainage and protection of *Phormium tenax* from flooding; in its nymphal stages the insect is located on the roots and leaf bases from March to November; here the nymphs are vulnerable to inundation lasting a few days, whereas it is known that the plant can withstanding flooding to a depth of two to three feet for periods up to four weeks during the winter months. Controlled flooding promises to provide a valuable control measure in some areas.

The part played by cutting operations, and other factors in transmitting the disease by mechanical means has not yet been investigated.

This is the first record in New Zealand both of a virus in an indigenous plant and of an endemic insect vector; examples of endemic viruses in endemic plants are rare; *Phormium* is endemic to New Zealand and Norfolk Island. The evidence to date suggests that the yellow-leaf virus is a new one and should it prove to be endemic, the relationship would be of interest particularly in view of New Zealand's long standing geographical isolation.

Detailed accounts of this work will be published in this Journal.

AIRBORNE MOULD SPORES

A SURVEY OF THE ATMOSPHERIC SPORE LOAD IN THE AUCKLAND CITY AND SUBURBAN AREA

By M. P. Ambler and T. R. Vernon, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 26 September 1949*)

For the purpose of investigating the relationship between airborne mould spores and allergic reactions, the Medical Research Council requested that a survey be made of the atmospheric spore load over New Zealand. Before undertaking this general survey, plate exposures were made in and about the city of Auckland. The results of this work are given below.

To determine the spore load over Auckland, six locations were selected for plate exposures. Two of these were in the city itself while the others were in suburban areas. Once a week throughout the year two 3½ in. petri dishes were exposed for five minutes at each location.

Altogether 3,431 mould colonies were counted, 2,370 (69 per cent) were identified, while 1,061 (31 per cent) remained unclassified. These either did not spore in culture or were very slow in sporing. Table I lists the moulds identified, and gives the frequency of appearance according to the district where plate exposures were made. Districts 1, 2, 3, and 4 were in the suburban, and districts 5 and 6 in the city area.

The most frequently occurring moulds were *Penicillium*, *Cladosporium*, Pycnidial types, *Epicoccum*, *Stemphylium* and *Alternaria*. Of these *Penicillium*, *Cladosporium* and the Pycnidial types showed little seasonal variation. On the other hand, *Stemphylium* was rarely encountered during the winter, but showed a sharp increase in numbers in late summer. *Epicoccum* and *Alternaria* also increased noticeably during the summer months.

Table II gives the mean numbers per plate according to month and district.

A general increase in numbers is observed during the warmer months. From May to November the mean numbers per plate varied from five to seven, while during the period from December to April they varied from eight to ten, except in January when the mean number per plate was 5.35. Plates exposed in the city gave the highest counts. The mean numbers per plate throughout the year for city areas were from eight to nine compared with five to six from suburban areas.

TABLE I

LIST OF MOULDS FOUND IN VARIOUS DISTRICTS IN AUCKLAND CITY AND SUBURBS

ORGANISM	SUBURBAN DISTRICTS				CITY DISTRICTS		TOTALS
	1	2	3	4	5	6	
Penicillium	36	48	61	24	153	268	590
Cladosporium	103	91	66	67	161	102	590
Pycnidial Forms	29	41	37	29	46	129	311
Epicoccum	61	42	51	21	51	21	247
Stemphylium	49	19	18	52	34	15	187
Alternaria	11	25	29	13	42	15	135
Pullularia	11	9	12	6	11	13	62
Pleospora Herbarum	9	7	13	8	4	11	52
Aspergillus	8	5	3	4	7	17	44
Trichoderma	4	4	2	.	7	17	34
Mucorales	3	.	2	2	8	15	30
Botrytis	6	6	6	4	4	2	28
Pestalozzia	2	.	3	1	1	2	9
Monilia	.	.	4	.	2	2	8
Fusarium	.	3	1	.	2	.	6
Gliocladium	1	2	.	2	.	.	5
Oospora	2	1	1	.	.	1	5
Helminthosporium	.	1	.	1	.	1	3
Verticillium	.	1	1	.	.	.	2
Periconia	.	.	.	1	1	.	2
Trichothecium	.	.	1	.	.	.	1
Nigrospora	.	.	1	.	.	.	1
Monosporium	1	1	1	.	.	.	3
Sepedonium	.	.	.	.	.	1	1
Curvularia	.	.	.	.	.	1	1
Cryptomela	1	.	.	.	.	.	1
Sporotrichum	.	1	.	.	.	.	1
Rhinocladium	.	.	.	.	1	.	1
Paecilomyces	.	.	.	.	.	1	1
Stysanus	.	.	.	.	.	1	1
Papularia	.	.	.	1	.	.	1
Cylindrocarpon	.	.	.	.	.	1	1
Torula	.	.	.	1	.	.	1
Rhizoctonia	2	.	.	.	1	.	3
Chaetomium	.	.	.	.	.	1	1
Neurospora	.	.	1	.	.	.	1
TOTALS	339	307	315	237	536	636	2370

TABLE II. MEAN NUMBER OF SPORES PER PLATE

DISTRICT	MONTH OF YEAR											
	July	August	September	October	November	December	January	February	March	April	May	June
1	8.29	3.00	2.25	2.75	3.00	11.50	4.33	12.33	8.63	12.50	3.63	2.80
2	5.29	3.50	2.67	4.88	4.33	7.50	5.33	9.00	5.50	5.50	8.63	3.60
3	2.00	1.83	1.75	1.71	6.20	2.00	7.50	5.75	8.50	7.80	7.75	7.30
4	5.00	3.00	3.67	4.00	2.00	4.75	2.33	11.75	6.13	11.20	5.00	4.20
5	14.00	5.75	6.00	5.00	7.33	16.00	6.00	12.20	7.00	13.56	5.75	6.30
6	8.00	10.88	10.20	10.25	12.00	7.00	6.00	11.50	10.50	11.20	9.13	6.40
MEAN	6.88	4.86	4.55	5.02	5.80	8.72	5.35	10.58	7.80	10.16	6.65	5.10

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